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TULANE STUDIES IN GEOLOGY AND PALEONTOLOGY

Volume 10

1972-1973

HUBERT G. SCHENCK

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TULANE STUDIES IN GEOLOGY AND PALEONTOLOGY is devoted primarily to the geology and paleontology of the coasts and adjacent land areas of the Gulf of Mexico and the Caribbean Sea. Each number contains an individual monographic study, or several minor studies. As volumes are completed, title pages and tables of contents will be distributed to subscribers and institutions exchanging the entire series.

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Hubert C. Skinner, *Editor*
Emily H. Vokes, *Associate Editor*
Ronald L. Parsley, *Exchange Director*
Tulane Studies in Geology and Paleontology
Department of Geology
Tulane University
New Orleans, Louisiana 70118
U.S.A.

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CERITHIIDAE AND POTAMIDIDAE (MOLLUSCA: GASTROPODA) FROM THE CHIPOLA FORMATION OF NORTHWESTERN FLORIDA

SHIRLEY E. HOERLE*
WEST PALM BEACH, FLORIDA

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I. ABSTRACT

This report covers 21 members of the families CERITHIIDAE and POTAMIDIDAE from the Chipola Formation, late lower Miocene, from northwestern Florida. Nine of Dall's species are reviewed; of these five have the generic assignment changed and one is placed in synonymy. Twelve species are added to the fauna of the Chipola Formation, two having been previously reported from elsewhere: *Terebralia dentilabris* (Gabb) and *Potamides suprasulcatus* (Gabb) from Santo Domingo. Ten species are new: *Cerithium peregrinum, Cerithium vokesorum, Hemicerithium craticulum, Hemicerithium pagodum, Hemicerithium akriton, Tenuicerithium absonum, Tenuicerithium ascensum, Cerithiopsis inopinus, Bittium serenum,* and *Alabina turbatrix.*

II. INTRODUCTION

The cerithiids of the Chipola Formation have been a group long neglected by previous authors. Dall (1892) recorded nine species:

*Research Associate, Paleontological Research Institution, Ithaca, New York.

EDITORIAL COMMITTEE FOR THIS PAPER:

THOMAS L. McGINTY, Boynton Beach, Florida.
EMILY H. VOKES, Tulane University, New Orleans, Louisiana.
DRUID WILSON, U. S. Geological Survey, Washington, D.C.

two *Cerithium,* five *"Bittium,"* one *"Clava,"* and one *Alaba,* from a limited amount of material. Since that time the cerithiids have been ignored except by Maury (1910) who mistakenly described a *Terebralia* as *Pyrazisinus.* The specimens she figured had complete apertures, which conceal the armature, a feature peculiar to the genus *Terebralia.* If the plaits on the columella and the interior protuberances are not visible the shell may be easily misidentified as *Pyrazisinus.* Gardner's monograph on the Molluscan Fauna of the Alum Bluff Group of Florida (1926-1947) mentioned only one Chipola species, *Alaba chipolana* Dall. She entirely overlooked the other members of the group. Cerithiids, particularly *Tenuicerithium* and one species of *Alabina,* abound at nearly every locality in the Chipola Formation. In the present study the writer has made no attempt to assign the various species to new subgenera but rather has tried to recognize only the existing subgenera and treat the genera in a broad manner.

The genus *Cerithium* originated in the Triassic Period and reached its maximum development during the Eocene epoch. The Recent species are found mainly in warm and temperate seas, often in the high tidal zone, or in mangrove swamps and mud flats. *Cerithium* s.s. is characterized by its turreted outline and numerous varices scattered at intervals along the many-whorled spire. The aperture is circular to oblique and prolonged into a short, recurved canal. Spiral cords cross axial riblets, forming nodes at their points of intersection. The heaviest varix is opposite the flaring outer lip. In the subgenus *Thericium* the characteristics are not as pronounced; the outer lip is only slightly expanded, the canal less recurved and the varix opposite the outer lip is weaker. Two new species described in this paper, *Cerithium peregrinum* and *Cerithium vokesorum,* and Dall's *Cerithium chipolana* are placed in the subgenus *Thericium.*

"Bittium" chipolanum and *"Bittium" permutabile* of Dall are here reassigned to the genus *Tenuicerithium.* They possess the essential features of *Tenuicerithium* as outlined by Cossmann: slender, tapered shell with large aperture and expanded outer lip; arcuate columella and a short, broad, not-recurved canal. The genus apparently became extinct during the Miocene epoch.

"Bittium" cossmanni Dall is removed from the genus *Bittium* and placed in *Hemicerithium.* The morphological characteristics of the species are more in accord with *Hemicerithium* than with *Bittium.* There are numerous varices on the spire; the columella is excavated; the canal is short and slightly oblique; the outer lip is nearly vertical and without inflection. The genus apparently appeared first in the Cretaceous. *Hemicerithium monachus* (Crosse and Fischer), the only Recent species, is confined to the Australian seas.

Clava chipolana Dall is reassigned to the subgenus *Ochetoclava* as *Clava* s.s. has a longer anterior canal and a shorter posterior sinus than *Ochetoclava* and is not represented by either fossil or Recent species in America.

It is unfortunate that Dall was so repetitive in his use of "Chipola," or a derivative, for his specific names. Boss, Rosewater and Ruhoff (1968, p. 4) state, "The frequency with which certain names were used by Dall is interesting because, at least in part, it reflects upon his associations and the areas of his scientific concentration. The names which were used more than ten times are listed in the order of their decreasing frequency: *chipolana-us* (53); *floridana-us* (33); *californica-us* (25); . . . . " Of the ten species of cerithiids he named from the Chipola Formation five are *chipolana-um.* Nothing can be done to emend this repetition as no two genera are the same. The names remain valid.

The genus *Triphora* is intentionally omitted in this paper. The writer feels that at the present time there is not adequate material at hand for a comprehensive study of the group. Further collecting is needed.

III. ACKNOWLEDGMENTS

The writer gratefully acknowledges the assistance of Drs. Harold E. and Emily H. Vokes of Tulane University, for without their encouragement, advice and unlimited patience this study could not have been completed. The writer is indebted to them for the excellent photographs and also the loan of

Tulane University specimens to supplement those in her own collection. Gratitude is expressed to Druid Wilson for providing the accurate data of Dall's type localities.

Special thanks are due the readers: Thomas L. McGinty, Boynton Beach, Florida; Druid Wilson, United States Geological Survey, Washington, D.C.; Emily H. Vokes, Tulane University, New Orleans, Louisiana, for their constructive criticisms and suggestions, which have added to the value of this paper.

IV. SYSTEMATIC DESCRIPTIONS

Phylum MOLLUSCA

Class GASTROPODA

Subclass PROSOBRANCHIA

Order MESOGASTROPODA

Superfamily CERITHIACEA

Family CERITHIIDAE Fleming, 1822

Subfamily CERITHIINAE Fleming, 1822

Genus CERITHIUM Bruguière, 1789

Cerithium BRUGUIÈRE, 1789, Encycl. Méth. (Vers), v. 1, p. XV (genus without species); 1792, *ibid.*, p. 467. Type species: *Cerithium adansonii* Bruguière (=*Cerithium erythraeonense* Lamarck, 1822), by virtual tautonymy.

Discussion: As has been noted by several authors (*e.g.*, Woodring, 1928, p. 333; Olsson and Harbison, 1953, p. 281), the type species of *Cerithium* Bruguière has been in a state of confusion for many years. Bruguière, 1789, did not designate a type for his genus *Cerithium*. However, Bruguière, 1792, did cite Adanson's "Le Cerite" (= *C. adansonii* Bruguière) in synonymy.

Lamarck, 1799, chose *Murex aluco* Linné for the type species. This shell belongs to the *Pseudovertagus* group. Lamarck apparently recognized his error as two years later he redescribed the genus and named *Cerithium nodulosum* Bruguière as the type species. A few authors credit Adanson [pre-Linnean] for the genus, several prefer Lamarck, but the majority recognize Bruguière.

Cossmann referred the genus to Bruguière but chose *Cerithium nodulosum* for the genotype. He placed special emphasis on the projecting tooth on the anterior of the outer lip and the manner in which it crosses the canal. This is a variable feature. The tooth may be strongly developed or totally absent on individuals of the same species.

Fisher-Piette (1942, p. 250-253, pl. 8, figs. 16a, b) clarified the muddle. *Cerithium adansonii* Bruguière is the same species as *Cerithium erythraeonense* Lamarck, 1822, from the Red Sea. Therefore, *Cerithium adansonii* Bruguière (= "Le Cerite" of Adanson) is a valid species and no longer enigmatical. Bruguière inferred, by placing *C. adansonii* in synonymy, that he selected that species for the genotype of *Cerithium* s. s. A ruling by the International Commission on Zoological Nomenclature would be beneficial in further clarifying the confusion of the previous years.

Subgenus THERICIUM Monterosato, 1890

Thericium MONTEROSATO, 1890, Naturalista Sicil., year 9, no. 7, p. 163. Type species: *Cerithium vulgatum* Bruguière, by original designation.

CERITHIUM (THERICIUM) CHIPOLANUM Dall

Plate 1, figs. 2, 3

Cerithium chipolanum DALL, 1892, Wagner Free Inst. Sci., Trans., v. 3, pt. 2, p. 285, pl. 22, fig. 7.
Cerithium chipolana Dall. WOOD, 1910, Annals N. Y. Acad. Sci., v. 20, no. 1, pt. 1, p. 45.

Diagnosis: "Shell of the general type of *C. thomasiae* Sowerby, but small, with three very small, smooth, compact nuclear whorls and eight subsequent rounded whorls; transverse sculpture of numerous small, rounded ribs extending across the whorl, and which are relatively stronger and more irregular, though less numerous, on the early whorls; the varices are quite irregular, some being strongly marked and others feeble; spiral sculpture of three or four primary, little-elevated, flattish threads, separated by wider interspaces, in which are two to four fine secondary threads; there are no beads or nodules, but the primaries appear conspicuous where they cross the ribs; similar sculpture extends over the base; aperture not much expanded, with a moderate callus and subsutural ridge on the body, a short, recurved canal and arched pillar." (Dall, 1892)

Dimensions of holotype: height 10.0 mm, diameter 4.5mm.

Holotype: USNM 113372.

Type locality: USGS 2213, one mile below Bailey's Ferry, Chipola River, Calhoun County, Florida (=TU 457).

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimens: Fig. 2, USNM 646939; height 15.0 mm, diameter 6.0 mm; locality TU 555. Fig. 3, USNM 646940; height 17.2 mm, diameter 7.4 mm; locality TU 549. Other occurrences: TU locality nos. 459, 547.

Discussion: C. chipolanum is not common in the Chipola marls and, as far as can be determined, is found only along the Chipola River within a geographic range of one mile. The majority of the specimens were recovered from TU 555. At this locality the shells are in a better than usual state of preservation and many retain traces of color pattern between the varices. This condition also was observed in specimens of *Tenuicerithium chipolanum.*

This species is variable, as can be noted by a comparison of figs. 2 and 3, plate 1. The first five post-nuclear whorls have numerous axial riblets crossed by three rounded spiral cords, usually forming small beads at their intersections. Subsequently the sculpture may change. The spiral cords may become flattened and broad, and anteriorly the axial ribs feeble, making a pattern of elongated nodes around the medial portion of the whorl. The outer lip is thickened to form a varix and is lirate within, the lirae corresponding to the primary spiral cords. One strong varix, opposite the aperture, is present on all specimens.

Although the type material purportedly came from "One mile below Bailey's Ferry" (= TU 457), after intensive field work neither Tulane University nor the writer's collection contains any specimens of *C. chipolanum* from this locality.

CERITHIUM (THERICIUM) PEREGRINUM
S. E. Hoerle, n. sp.

Plate 1, fig. 4

Diagnosis: Nuclear whorls lost, ten flat to rounded teleoconch whorls in the adult. Periphery about half-way between distinct, appressed sutures. On the early whorls eleven axial riblets, reaching from suture to suture, later axials diminishing in length, on terminal whorl becoming little more than long nodes immediately in front of the suture. One broad varix opposite outer lip. Spiral sculpture consisting of narrow flat cords, with one or two intercalated threads over entire shell. Small nodes formed on the body whorl where the spiral cords cross the nearly obsolete axials. Aperture broadly ovate, outer lip flaring and projecting forward, ascending to form a deep posterior sinus. Inner lip with heavy callus and subsutural ridge. Anterior canal short, broad, oblique, recurved to left.

Dimensions of holotype: height 24.3 mm, diameter 10.5 mm.

Holotype: USNM 646941.

Type locality: TU 546, Ten Mile Creek, about 1½ miles west of Chipola River (NW ¼ Sec. 12, T1N, R10W), Calhoun County, Florida (?=USGS 2212, "one mile west of Bailey's Ferry").

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimen: USNM 646941 (holotype). Other occurrences: TU locality no. 830.

Discussion: C. peregrinum is described from one nearly complete specimen and one fragment, but the sculpture is so distinctive that it cannot be confused with any other species from the Chipola Formation. *C. microlineatum* Gabb, 1873, from the Gurabo Formation of Santo Domingo has a similar sculpture but the shell is proportionately more slender and considerably larger. Another related Santo Domingo species, *C. gurabense* Maury, 1917, has a more slender outline and is not as constricted at the base of the body whorl. *C. peregrinum* shows a definite relationship with the two above mentioned species; however, the significant characteristics are sufficiently dissimilar to warrant the new specific name.

CERITHIUM (THERICIUM) VOKESORUM
S. E. Hoerle, n. sp.

Plate 1, fig. 5

Diagnosis: Shell slender, tapering, consisting of ten or eleven slightly rounded whorls and a nucleus of 2+ whorls. Axial riblets unevenly spaced, extending from suture to suture, usually eight or nine to a turn, every fourth or fifth one a little heavier. Small beads may be formed where the three primary flat spirals cross the axial riblets. Small, smooth, flattened threads present in the interspaces. Sutures deep but not channeled, bordered posteriorly by one small cord. Three raised, heavy, smooth cords encircling the base. Aperture small, ovate-rounded with a shallow posterior sinus. Inner lip with callus and small subsutural fold. Outer lip with varix and projecting edge, deeply jagged within to correspond with primary spirals. Canal short, recurved, truncated. The strongest varix opposite the outer lip.

Dimensions of holotype: height 18.5 mm, diameter 6.0 mm.

Holotype: USNM 646942.

Type locality: TU 825, Farley Creek at abandoned mill about ¼ mile west of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N,R9W), Calhoun County, Florida.

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimen: USNM 646942 (holotype). Other occurrences: TU locality nos. 457, 458, 459, 547, 548, 554, 818, 820b, 821, 826, 827, 828, 950, 999.

Discussion: Present collections indicate that *C. vokesorum* is confined to the areas of the Chipola River and Farley Creek. Only a limited number of individuals have been taken from each locality listed. The largest example in the Tulane University collections (TU 548) is an eroded specimen measuring 22.0 mm, others are considerably smaller. The outer lips and canals are fragile and consequently more often than not badly broken. The greatest variability is found in the strength of the primary spiral ribs, which at times are so weak that no beading is discernible and the axial riblets appear almost smooth.

The writer takes great pleasure in naming this new species *Cerithium vokesorum* in honor of Dr. Harold E. and Mrs. Emily H. Vokes whose untiring patience, constant encouragement and invaluable assistance have made this paper possible.

CERITHIUM (SUBGENUS ?) BURNSII Dall

Plate 1, fig. 1

Cerithium burnsii DALL, 1892, Wagner Free Inst. Sci., Trans., v. 3, pt. 2, p. 280, pl. 14, fig. 12.
Cerithium (Ptychocerithium) burnsii Dall. COSSMANN, 1906, Essais Paléoconch. Comp., v. 7, p. 142.

Diagnosis: "Shell solid, strong, nuclear whorls lost, with ten or more subsequent whorls; spiral sculpture of seven or eight revolving, flattened threads, with narrower, channelled interspaces, variable in size; one at the periphery, another on which the suture is wound, and one or two more on the base, being larger than the rest; the surface of the specimens is somewhat worn, but there are hardly any indications of fine spiral striation; the spirals on the last whorl are somewhat wavy, that on the basal margin and those near the suture on the last whorl have some tendency to become nodulated; transverse sculpture of about eight narrow, strong, rounded ribs extending across the whorls and angulated at the intersection of the peripheral spiral; one of these on each whorl is a little larger than the others, but the only conspicuous varix is that at the end of the first third of the last whorl; suture distinct, appressed; base somewhat excavated; pillar short, arched, simple; canal narrow, deep, recurved; body with a strong callus with its edge free; outer lip thickened, arched, with faint sulci inside corresponding to the sculpture; at the junction with the body is a moderate sinus and sub-sutural, elevated ridge which enters the throat some distance." (Dall, 1892)

Dimensions of holotype: height 55 mm, diameter 20 mm.

Holotype: USNM 113354.

Type locality: USGS 2211, Alum Bluff (lower bed), Apalachicola River (NE ¼ Sec. 24, T1N, R8W), Liberty County, Florida (= TU 453). [Incorrectly reported in Dall, 1892, p. 280, as "Upper beds."]

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimen: USNM 646938; height 64.6 mm, diameter 22.7 mm; locality TU 825. Other occurrences: TU locality nos. 458, 459, 547, 554, 555, 821, 830, 950, 951, 999, 1019, 1050.

Discussion: Dall (1892, p. 280) described *C. burnsii* from "Newer or Chesapeake Miocene of the upper bed at Alum Bluff on the Chattahoochee River, Florida." The type was labeled with USGS 2211, which is the number for the lower bed of Alum Bluff on the Apalachicola River. This locality is confirmed by remaining traces of the matrix which is a red sand. The upper bed is of gray marl. (Druid Wilson, 1970, *in litt.*)

While this species cannot be considered a common shell at any one locality in the Chipola Formation it is rather widely distributed, being collected from the banks of Farley Creek and Ten Mile Creek as well as the Chipola River, also the lower bed at Alum Bluff. The majority of the specimens are not complete and seldom are the earlier whorls preserved, as the shell tapers to an almost needle-like point. One fragmentary specimen retains the nucleus of 2+ whorls and five gradually enlarging whorls with about fifteen faint axial riblets crossed by eight or nine spiral threads, making a reticulate pattern. The teleoconch whorls are

in accord with Dall's description. Adjoining the main siphonal canal is a small residual canal, curving backwards and to the left, situated directly anterior to the final varix which is opposite the outer lip.

C. burnsii is the largest of the Chipola cerithiids and is distinguished by its moderately long, sharply recurved anterior canal, the slit-like posterior sinus formed by the ascending outer lip and the upturned remnant of a former canal.

Cossmann (1906, pp. 82, 142) assigned *C. burnsii* to the subgenus *Ptychocerithium.* The writer does not agree with his opinion. Neither should it be placed in the subgenus *Thericium* nor *Cerithium* s.s. Because of the unusual feature of the residual canal, possibly a new subgenus should be erected for this species.

Genus HEMICERITHIUM Cossmann, 1893

Hemicerithium COSSMANN, 1893, Jour. de Conchyl., v. 41, p. 302. Type species: *Cerithium imperfectum* Deshayes, by original designation.

HEMICERITHIUM COSSMANNI (Dall)

Plate 2, fig. 3

Bittium cossmanni DALL, 1892, Wagner Free Inst. Sci., Trans., v. 3, pt. 2, p. 273, pl. 21, fig. 16.
Hemicerithium cossmanni (Dall). COSSMANN, 1906, Essais Paléoconch. Comp., v. 7, p. 103.
Hemicerithium cossmanni (Dall). GLIBERT, 1962, Mém. Inst. Roy. Sci. Nat. Belg., (Ser. 2) fasc. 69, p. 212.

Diagnosis: "Shell subconic, with two and a half smooth, rounded nuclear whorls and six or seven rapidly increasing, inflated subsequent whorls; varices numerous, usually two or three on each of the larger whorls, with three small, peripheral, wavelike, transverse riblets between each pair of varices, or the riblets may be obsolete; spiral sculpture of fine straie with wider interspaces, forming fine, flattish threads, with one wider flat thread just in front of the periphery, and in advance of that one another on which the suture is wound; suture very distinct, deep, subappressed; periphery nearer the anterior suture; base spirally threaded, rounded; aperture wide, pillar very short and feeble, canal short, wide; outer lip arched, slightly thickened, not lirate within, a thin wash of callus on the inner lip." (Dall, 1892)

Dimensions of holotype: height 11.0 mm, diameter 5.5 mm.

Holotype: USNM 113331.

Type locality: USGS 2213, one mile below Bailey's Ferry, Chipola River, Calhoun County, Florida (=TU 457).

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimen: USNM 646951; height 14.4 mm, diameter 6.4 mm; locality TU 825. Other occurrences: TU locality nos. 70, 196, 456, 457, 458, 459, 546, 547, 548, 549, 554, 555, 655, 711, 806, 818, 820b, 821, 826, 828, 830, 950, 951, 998, 999, 1020, 1021, 1050.

Discussion: Cossmann, in his discussion of *Hemicerithium* (1906, p. 103), stated: "Une espèce absolument typique, dans l'Aquitanien de la Florida: *Bittium cossmanni* Dall, ma coll." *"Bittium" cossmanni* is certainly better placed in the genus *Hemicerithium,* as the specimens under discussion do not have the characteristics that distinguish the genus *Bittium.* These would include an anal sinus, a sharp edge on the inner lip, the body whorl smaller than the penult and the sculpture reticulated.

Hemicerithium cossmanni is a common species in the Chipola Formation. Adult specimens, with nine whorls, vary in length from 14.0 mm to 19.0 mm. Regardless of size the sculpture and subconic outline remain the same as in Dall's description. The early post nuclear whorls are identical to those of *H. akriton,* n. sp., as they also are carinated and ornamented with tiny nodes on the periphery. The heavy varices do not appear until the third or fourth whorl. Dall stated that the lip is slightly thickened but in none of the over 900 specimens examined by the writer has this been verified. Perhaps the lip was broken at a heavy varix, this often happens, which could have given him that impression. The stronger varices appear as bulges inside the aperture.

HEMICERITHIUM AKRITON
S. E. Hoerle, n. sp.

Plate 2, fig. 1

Diagnosis: Shell conic; nine to ten teleoconch whorls in adult plus 2½ nuclear whorls. Periphery of whorls on anterior third, outlined by eight or nine strong, elongate nodes reaching from medial portion of whorl to anterior suture. Posterior slope concave

to flat, sculptured by irregularly spaced, revolving, flat threads. Sutures distinct, appressed, undulated by nodes of preceeding whorl. Base of shell flat to slightly convex, sculptured by numerous flat threads of varying widths, narrow interspaces. Aperture subquadrate; columella with a wash of callus; canal short, truncate.

Dimensions of holotype: height 18.4 mm, diameter 12.3 mm.

Holotype: USNM 646950.

Type locality: TU 820b, Farley Creek (lower beds), at bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun County, Florida.

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimen: USNM 646950 (holotype). Other occurrences: TU locality nos. 546, 547, 555, 818, 821, 825, 826, 999.

Discussion: The spiral sculpture of *H. akriton* is exceedingly variable. A few specimens (particularly those from TU 555) have a wide sub-sutural collar, others may have a rounded cord preceeding the suture, and many have neither feature. The size of an adult (nine to ten whorls) ranges between 16.0 mm and 20.0 mm, although some specimens may occasionally reach 25.0 mm. At this stage the outline of the body whorl changes, becoming more rounded with the nodes becoming more feeble. The base acquires a convexity not seen in an average size individual. The compact "Christmas tree" outline and the wavy suture are criteria to differentiate this species from other members of the *Hemicerithium.*

A species of *Hemicerithium* that may be ancestral to *H. akriton* occurs in the Tampa Limestone. Dall (1915, p. 89, pl. 13, fig. 10) described and figured *"Bittium" adela* from a single juvenile specimen. Further collecting produced five topotypes, which are in the U. S. National Museum. Examination of these specimens clearly shows that the whorls of *H. adela* always have an anterior slope, the sutures are grooved, and the shell does not attain the size of *H. akriton.* The holotype of *"Bittium" adela* is refigured here, pl. 2, fig. 2, for comparison.

HEMICERITHIUM CRATICULUM

S. E. Hoerle, n. sp.

Plate 2, fig. 4

Diagnosis: Shell small; 2+ glassy nuclear whorls, eight to ten bicarinate teleoconch whorls; periphery on anterior half of whorl. Six to eight raised spiral threads on posterior flattened slope; five threads between carinae, middle one slightly stronger; three or four threads on short concave anterior slope, and one heavy cord upon which the subappressed suture is laid. Numerous faint axial riblets over entire shell, giving the intercarinal spaces a latticed appearance. Occasional heavy varices, about two per turn on later spire whorls and body whorl. Body whorl terminated by the sutural cord; base somewhat flattened with eight to ten alternating fine and heavy revolving threads. Aperture subquadrate, canal short and oblique.

Dimensions of holotype: height 10.8 mm, diameter 3.7 mm.

Holotype: USNM 646952.

Type locality: TU 998, Ten Mile Creek, about 1¼ miles west of Chipola River (SE ¼ Sec. 12, T1N, R10W), Calhoun County, Florida.

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimen: USNM 646952 (holotype). Other occurrences: TU locality nos. 70, 546, 806, 817, 821, 825, 951.

Discussion: The majority of the specimens of this unusual species were taken from localities on Ten Mile Creek, TU 546 yielding 116 specimens. *H. craticulum* may be distinguished from other members of the genus by its angular outline, strong carinae, and its lattice-like sculpture. The columella is slightly excavated and occasionally covered by a wash of callus.

HEMICERITHIUM PAGODUM

S. E. Hoerle, n. sp.

Plate 2, fig. 5

Diagnosis: Shell small, slender, elongated; nucleus 2+ rounded glassy whorls, eight to ten angulated post-nuclear whorls with submedian periphery. Posterior slope slightly concave and undulated by faint axial riblets (about ten), which increase in size anteriorly and become obsolete after crossing the periphery. Heavier varices may be scattered along the spire. Anterior slope short and steep. Suture distinct but not channeled. Spiral sculpture consisting of microscopic threads with equal-sized interspaces; one heavier thread outlining the periphery forming nodes at points of intersection with varices. Another heavier thread just behind the suture and terminating the body whorl, forming a carina, base constricted. Aperture subquadrate; arcuate columella with a wash of callus; canal short, oblique and truncated.

Dimensions of holotype: height 8.5 mm, diameter 3.2 mm.

Holotype: USNM 646953.

Type locality: TU 825, Farley Creek at abandoned mill about ¼ mile west of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun County, Florida.

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimen: USNM 646953 (holotype). Other occurrences: TU locality nos. 458, 459, 547, 548, 554, 555, 821, 826.

Discussion: H. pagodum is the least common of the four species of *Hemicerithium* in the Chipola Formation and is confined to collections from Farley Creek and the Chipola River. Although this new species has a superficial resemblance to *H. cossmanni* in its spiral sculpture and peripheral nodes, the outline of the two species is entirely different. The

PLATE 1

Figures — Page

1. *Cerithium burnsii* Dall (X 1½) 5
   USNM 646938; height 64.6 mm, diameter 22.7 mm.
   Locality: TU 825. Chipola Fm., lower Miocene.

2, 3. *Cerithium (Thericium) chipolanum* Dall 3
   2. (X 3) USNM 646939; height 15.0 mm, diameter 6.0 mm.
      Locality: TU 555. Chipola Fm., lower Miocene.
   3. (X 3) USNM 646940; height 17.2 mm, diameter 7.4 mm.
      Locality: TU 549. Chipola Fm., lower Miocene.

4. *Cerithium (Thericium) peregrinum* S. E. Hoerle, n. sp. (X 2) 4
   USNM 646941 (holotype); height 24.3 mm, diameter 10.5 mm.
   Locality: TU 546. Chipola Fm., lower Miocene.

5. *Cerithium (Thericium) vokesorum* S. E. Hoerle, n. sp. (X 3) 4
   USNM 646942 (holotype); height 18.5 mm, diameter 6.0 mm.
   Locality: TU 825. Chipola Fm., lower Miocene.

6. *Rhinoclavis (Ochetoclava) chipolana* (Dall) (X 3) 12
   USNM 646943; height 22.4 mm, diameter 7.6 mm.
   Locality: TU 825. Chipola Fm., lower Miocene.

7, 8. *Potamides suprasulcatus* (Gabb) 17
   7. (X 2) USNM 646944; height 30.4 mm, diameter 15.4 mm.
      Locality: TU 459. Chipola Fm., lower Miocene.
   8. (X 3) USNM 646945; height 11.0 mm, diameter 5.1 mm.
      Locality: TU 459. Chipola Fm., lower Miocene.

9-11. *Terebralia dentilabris* (Gabb) 20
   9. (X 3) USNM 646946; height 16.7 mm, diameter 7.6 mm.
      Locality: TU 459. Chipola Fm., lower Miocene.
   10. (X 1½) USNM 646947; height 49.0 mm, diameter 21.6 mm.
      Locality: TU 459. Chipola Fm., lower Miocene.
   11. (X 1½) USNM 646948; height 53.7 mm, diameter 23.5 mm.
      Locality: TU 459. Chipola Fm., lower Miocene.

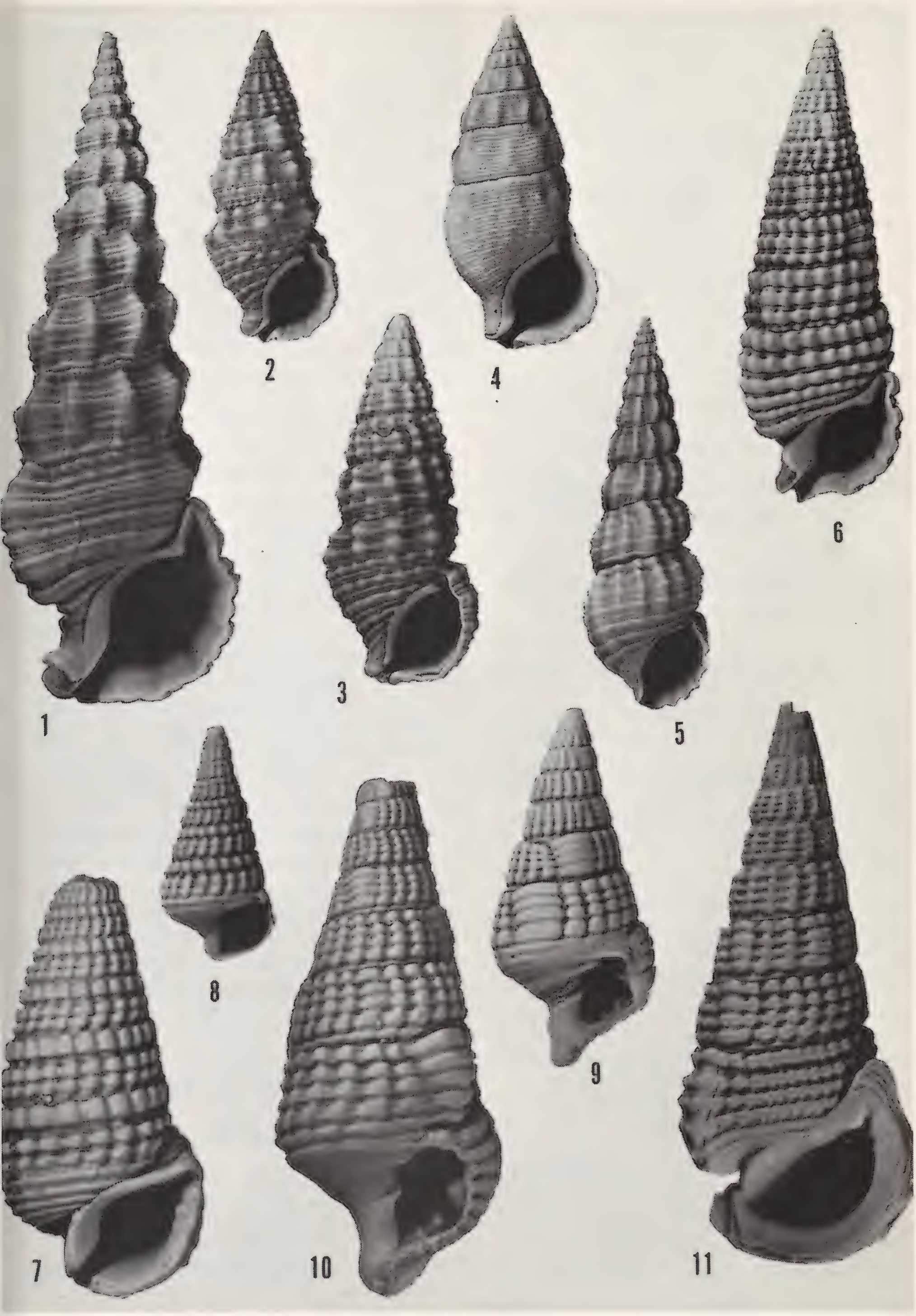

PLATE 1

whorls of *H. pagodum* have an angular appearance, while those of *H. cossmanni* are rounded. Also, *H. pagodum* always retains its slender, delicate form and small size. The only noticeable variability is in the peripheral nodes. On the majority of specimens the nodes are slightly upturned but a few specimens have the nodes projecting at a 90 degree angle to the axis. The revolving threads cannot be seen without magnification. The thin, flaring lip is always broken back, including the figured specimen.

Genus TENUICERITHIUM
Cossmann, 1896

Tenuicerithium COSSMANN, 1896, Cat. Illus. Coq. Foss. Éocène Paris, Append. 2, *in* Soc. Roy. Malac. Belg., Ann., v. 31, p. 30. Type species: *Cerithium fragile* Deshayes, by original designation.

TENUICERITHIUM CHIPOLANUM (Dall)
Plate 2, figs. 6, 7

Bittium chipolanum DALL, 1892, Wagner Free Inst. Sci., Trans., v. 3, pt. 2, p. 272, pl. 21, fig. 15.
Bittium chipolanum var. *burnsii* DALL, 1892, Wagner Free Inst. Sci., Trans., v. 3, pt. 2, p. 272, pl. 21, fig. 18.
Tenuicerithium chipolanum (Dall). COSSMANN, 1906, Essais Paléoconch. Comp., v. 7, p. 142.
Tenuicerithium chipolanum (Dall). GLIBERT, 1962, Mém. Inst. Roy. Sci. Nat. Belg., (Ser. 2) fasc. 69, p. 197.

Diagnosis: "Shell acute, with four larval, at first smooth, afterward spirally threaded, rounded whorls, and about ten subsequent flattened whorls, widest immediately behind the suture; surface spirally grooved, with the interspaces wider than the grooves, and one especially wide one usually at the periphery; transverse sculpture of about sixteen nearly straight, rounded riblets, usually beginning in front of the suture and growing wider and stronger to the periphery, where they cease abruptly, or they may be obsolete or entirely absent; they are usually faint or absent on the last whorl, even when they are strong on the rest of the shell; base strongly, spirally grooved and threaded, with a single swollen, ill-defined varix about half a turn behind the outer lip; there are no varices on the other whorls except in rare cases; suture distinct, applied below the periphery so that a single thread intervenes behind the suture and in front of the ends of the ribs; canal short, straight, wide, shallow; outer lip thin, not reflected; inner lip slightly callous; pillar somewhat curved, slender; throat slightly or not at all lirate." (Dall, 1892)

Dimensions of holotype: height 13.0 mm, diameter 3.75 mm.

Holotype: USNM 113328.

Type locality: USGS 2213, one mile below Bailey's Ferry, Chipola River, Calhoun County, Florida (=TU 457).

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimens: Fig. 6, USNM 646954; height 14.4 mm, diameter 5.0 mm; locality TU 825. Fig. 7, USNM 646955; height 13.6 mm, diameter 4.4 mm; locality TU 825. Other occurrences: TU locality nos. 70, 196, 457, 458, 459, 546, 547, 548, 549, 554, 555, 655, 787, 806, 817, 818, 820b, 821, 826, 827, 828, 830, 950, 951, 998, 999, 1020, 1021, 1050.

Discussion: Dall (1892, p. 272) named a variety of *T. chipolanum* as *"Bittium" chipolanum burnsii* (holotype USNM 113329) and stated that the latter is a more slender shell with several varices and with the body whorl proportionally smaller. Examination of only a few specimens could easily lead one to believe there are two distinct species. The writer had nearly 8,000 specimens from thirty localities at her disposal; a study of which clearly indicated that there is a great variability as to the number and placement of the heavy varices on *T. chipolanum* (compare pl. 2, figs. 6 and 7). As no specific differences can be discerned, variety *burnsii* is here placed in synonymy with *T. chipolanum* s. s.

T. chipolanum is by far the most common member of the subfamily Cerithiinae, being found at nearly every locality thus far collected. It is easily distinguished by the straight sided, slightly overhanging whorls, the expanded outer lip with a suggestion of a posterior sinus and the short, broad canal.

TENUICERITHIUM PERMUTABILE (Dall)
Plate 2, fig. 12

Bittium permutabile DALL, 1892, Wagner Free Inst. Sci., Trans., v. 3, pt. 2, p. 272, pl. 21, fig. 17.
Tenuicerithium permutabile (Dall). COSSMANN, 1906, Essais Paléoconch. Comp., v. 7, p. 142.
Tenuicerithium permutabile (Dall). GLIBERT, 1962, Mém. Inst. Roy. Sci. Nat. Belg., (Ser. 2) fasc. 69, p. 198.

Diagnosis: "Shell acute, with two very minute, smooth, rounded nuclear whorls and about ten subsequent, also rounded, whorls, with the periphery almost midway between the sutures; suture closely appressed, distinct, not marginate, varices irregular, generally two or three in number, distributed along the spire; spiral sculpture of numerous fine, close-set, sometimes alternated, rounded threads; transverse sculpture of about nine prominent, rounded riblets, bigger at the periphery, narrowing and becoming feeble each way toward the suture; base spirally threaded, aperture with a feeble canal, short and twisted pillar and non-lirate throat; outer lip thin, simple, arched forward; inner lip slightly washed with callus; last varix strong and prominent." (Dall, 1892)

Dimensions of holotype: height 13.5 mm, diameter 3.75 mm.

Holotype: USNM 113330.

Type locality: USGS 2213, one mile below Bailey's Ferry, Chipola River, Calhoun County, Florida (=TU 457).

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimen: USNM 646960; height 12.6 mm, diameter 3.8 mm; locality TU 546. Other occurrences: TU locality nos. 457, 458, 459, 547, 548, 549, 554, 555, 806, 817, 820b, 821, 825, 826, 951, 998, 1020, 1021, 1050.

Discussion: Cossmann (1906, p. 142) mentioned two species in the "Aquitanian" beds of Florida that are typical of the genus *Tenuicerithium* Cossmann, 1896: *"Bittium" chipolanum* and *"Bittium" permutabile*. The writer feels no hesitation in agreeing with Cossmann's assignment. Both species have a large aperture, outer lip expanded forward and a short, broad, not recurved anterior canal.

The number and placement of axial riblets as well as the number of spiral cords are not constant from individual to individual. The periphery may be medial or slightly submedial giving a dissimilar aspect in profile. *T. permutabile* is common on the Chipola River, Farley Creek and lower beds of Ten Mile Creek. Over 5,000 specimens were collected from the river locality TU 555. This species has not been taken from the higher beds along Ten Mile Creek.

TENUICERITHIUM ABSONUM

S. E. Hoerle, n. sp.

Plate 2, fig. 10

Diagnosis: Shell consisting of ten to twelve whorls, plus 2½ nuclear whorls; early six or seven teleoconch whorls flat-sided and sutures deeply grooved; remaining whorls rounded and sutures moderately grooved. Early post-nuclear whorls of shell ornamented with about ten narrow, evenly spaced, axial riblets crossed by two, increasing to three, rounded spiral cords. After sixth or seventh turn sculpture changes abruptly; whorls expanding rapidly, spiral cords decreasing in strength and increasing in number, thirteen on the final turn; axial riblets replaced by heavy varices, three or four to a whorl. Aperture subovate with a feeble canal, outer lip thin and flaring, inner lip with a wash of callus.

Dimensions of holotype: height 13.2 mm, diameter 4.8 mm.

Holotype: USNM 646958.

Type locality: TU 555, east bank of Chipola River, about 1000 feet above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun County, Florida.

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimen: USNM 646958 (holotype). Other occurrences: TU locality no. 547.

Discussion: T. absonum resembles *T. permutabile* in the later whorls; however, the early whorls are entirely dissimilar. In outline *T. absonum* is stouter and more rugose and the first six or seven post-nuclear whorls are flat-sided and the sutures are deeply grooved. The axial riblets extend from suture to suture in the new species whereas in *T. permutabile* they fade both posteriorly and anteriorly on the whorls. Over 500 specimens of *T. absonum* were collected at two closely approximate localities (TU 555 and TU 547). These same two localities yielded an abundance of *T. permutabile*. There is evidence of a close relationship between the two species and undoubtedly *T. absonum* is an offshoot of *T. permutabile*. Apparently the conditions were optimum for trying a new line, but for an unknown reason, *T. absonum* was restricted to a limited geographic area.

TENUICERITHIUM ASCENSUM

S. E. Hoerle, n. sp.

Plate 2, fig. 11

Diagnosis: Shell turriform, moderately stout. Nucleus unknown; nine post-nuclear whorls in adult. Axial sculpture consisting of seven to nine short, heavy varices; medially positioned on early whorls, posteriorly positioned on later whorls, giving a knobby shouldered outline in profile. Spiral cords broad, rounded; two on early whorls, gradually increasing to seven on penultimate and body whorl. Only the three posterior cords, on later whorls, cross

the short axial riblets, coalescing on summits; deep pit-like interspaces between axial knobs. Three widely spaced flat spiral cords on constricted base. Aperture large, subovate; outer lip expanding forward; inner lip callused; canal broad, short, not recurved.

Dimensions of holotype: height 9.7 mm, diameter 3.9 mm.

Holotype: USNM 646959.

Type locality: TU 459, east bank of Chipola River, steep bank about 1500 feet above the mouth of Taylor Lake Branch (NW ¼ Sec. 29, T1N, R9W), Calhoun County, Florida.

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimen: USNM 646959 (holotype).

Discussion: Tenuicerithium ascensum is known from one locality only (TU 459) and is represented by 27 specimens, the majority of which show some degree of corrosion. The step-like outline of the whorls and the pit-like interspaces between the abbreviated varices are the criteria that enable this new species to be separated from all other cerithiids of the Chipola Formation. Although the holotype is somewhat atypical of the species (the intervarical areas are not as excavated), it is the best preserved of the lot and is selected for that reason. The type specimen and a juvenile of the species were found inside a large *Melongena* and consequently were in better condition. TU 459 apparently was near the mouth of a river, as the associated fauna from the locality shows the effects of tumbling and a goodly amount of corrosion. The matrix is of a gravelly nature and mainly quartz pebbles.

Genus RHINOCLAVIS Swainson, 1840

Rhinoclavis SWAINSON, 1840, Treatise Malac., pp. 157, 315. Type species: *Cerithium vertagus* (Linné), by subsequent designation, Herrmannsen, 1848.

Subgenus OCHETOCLAVA Woodring, 1928

Ochetoclava WOODRING, 1928, Carnegie Inst. Washington, Publ. 385, p. 334. Type species: *Cerithium gemmatum* Hinds, by original designation.

RHINOCLAVIS (OCHETOCLAVA) CHIPOLANA (Dall)

Plate 1, fig. 6

Clava chipolana DALL, 1892, Wagner Free Inst. Sci., Trans., v. 3, pt. 2, p. 290, pl. 22, fig. 8.

Diagnosis: "Shell small for the genus, with two extremely minute, smooth nuclear whorls and thirteen to fifteen subsequent sculptured whorls; the tip of the spire is very acute, from about the seventh whorl it is enlarged more rapidly in proportion; the early whorls have about seven sharply elevated narrow ribs, extending across the whorls, with wider interspaces, over which run three strap-like spirals with about equal channelled interspaces, prominent but not nodulous at the intersections; the ribs gradually get more numerous and close-set, so that the reticulations are about square, and between the spirals a small intercalary thread appears which becomes wavy on the last whorl; the varix occurs at the end of the first third of the last whorl, and beyond it the ribs are obsolete; the last whorl has six prominent and as many intercalary spirals behind the base, which has three or four somewhat smaller rippled primaries and an equal number of intercalary simple threads; outer lip thickened, not reflected, slightly sulcate in harmony with the external spirals; body with a well-marked subsutural ridge and notch outside of it, and with a moderate callus; pillar short, with a thick, elevated callus and a strong plait about the middle; canal short, reflected; varix swollen, not very prominent; suture appressed, distinct." (Dall, 1892)

Dimensions of holotype: height 22.0 mm, diameter 7.5 mm.

Holotype: USNM 114281.

Type locality: USGS 2211, Alum Bluff (lower bed), Apalachicola River, Liberty County, Florida (=TU 453).

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimen: USNM 646943; height 22.4 mm, diameter 7.6 mm; locality TU 825. Other occurrences: TU locality nos. 70, 196, 453, 456, 457, 458, 459, 546, 547, 548, 549, 554, 555, 655, 711, 806, 817, 820b, 821, 826, 830, 950, 951, 998, 999, 1020, 1049, 1050.

Discussion: R. chipolana is related to the Mio-Pliocene species *R. caloosaensis* (Dall). The latter is a larger shell with less pronounced sculpture and a tendency to wider spiral cords, particularly the one anterior to the suture, thus giving the whorls the appearance of having a subsutural band. The early whorls, (six or seven) of *R. chipolana* are sharply tapered and have only seven to nine

axial riblets (on *R. caloosaensis* the riblets are close set) crossed by three spiral threads, the medial and anterior spiral threads forming nodes at the points of intersection. The axial riblets increase in number and the spiral cords become heavier until the whorls are covered by a reticulated pattern and appear flat-sided. Secondary spiral threads may be intercalated between the primary spirals on later whorls and one beaded thread lies just behind the suture. Low varices may or may not be scattered over the spire.

In the fauna of the Oak Grove Sand, which is probably only a facies of the Chipola Formation, there is another species of *Rhinoclavis* much like *R. chipolana.* This species, originally named *Cerithiopsis ogilvies* Maury (1910, p. 27, pl. 7, fig. 3), is a much smaller and more slender shell with notable differences in its ornamentation. The primary spiral cords on *R. chipolana* are heavy and broad, whereas those on *R. ogilvies* have the appearance of beads on a string. Ofttimes the posterior cord of the Chiopla species has a tendency to be the largest of the three. If any of the primary spiral cords on *R. ogilvies* are enlarged, it is invariably the anterior one. Examination of 29 lots of Chipola specimens shows that the placement of the intercalary threads on the spire whorls is not a constant feature, as some of the whorls may be completely devoid of ornamentation between the primary cords. The small threads on the Oak Grove specimens are more consistent in their appearance and relatively more prominent. The flange-like projection of the callus on the inner lip, which is so pronounced on the Chipola species, is more subdued on the Oak Grove specimens. A comparison of pl. 1, fig. 6, with pl. 2, fig. 18, will show that, although the two forms are similar, the differences do warrant the recognition of two species. *R. ogilvies* is the only cerithiid that is present in the fauna of the Oak Grove Sand (Maury also described a 4 mm species of *Bittium,* which has not been found) but it is a moderately common gastropod in what is a predominantly pelecypod fauna.

Woodring (1928, p. 335) stated, "This subgenus [*Ochetoclava*] is represented in the Miocene deposits of Florida and the Caribbean region and even in the Pliocene of Florida, but probably is extinct there . . . . " Subsequent collecting to date has not refuted Dr. Woodring's statement.

Subfamily CERITHIOPSINAE H. and A. Adams, 1853

Genus CERITHIOPSIS Forbes and Hanley, 1853

Cerithiopsis FORBES and HANLEY, 1853, History of British Mollusca, v. 3, p. 364. Type species: *Murex tubercularis* Montagu, by monotypy.

CERITHIOPSIS INOPINUS S. E. Hoerle, n. sp.

Plate 2, fig. 14

Diagnosis: Shell small, slender, slightly tapered; nine to ten whorls in adult plus nucleus of four whorls. Initial whorl of nucleus smooth, other three marked with faint axial riblets. Teleoconch sculpture consisting of numerous axial ribs crossed by rounded spiral cords, forming a cancellate pattern; two spiral cords on first post-nuclear whorl, increasing to three on successive whorls. Body whorl terminated by a fourth spiral cord, not noded by the axial ribs. Sutures narrow, grooved. Incremental axial sculpture on constricted base; one obscure cord encircling end of pillar. Aperture subovate; outer lip flaring anteriorly, inner lip slightly callused. Siphonal canal short, open, truncated anteriorly.

Dimensions of holotype: height 4.0 mm, diameter 1.3 mm.

Holotype: USNM 646962.

Type locality: TU 555, east bank of Chipola River about 1000 feet above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun County, Florida.

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimen: USNM 646962 (holotype). Other occurrences: TU locality no. 547.

Discussion: This new species is the sole representative of the genus *Cerithiopsis* in the Chipola Formation. Maury (1910, p. 27, pl. 7, fig. 3) named a species *Cerithiopsis ogilvies,* and gave the locality as "Oak Grove and Bailey's Ferry". In her description she stated that the shell had "varices about nine in all, only the two on the body-whorl being pronounced". *Cerithiopsis* have no strong varices on the body whorl or on the spire, no sutural sinus nor subsutural ridge on the labium and do not have a recurved canal,

thus her generic assignment is in error. Her figure depicts a small and delicate shell very reminiscent of *Rhinoclavis chipolana,* a common species in the Chipola fauna. Maury's species is further discussed in this paper with *Rhinoclavis chipolana.* (See pl. 2, fig. 18 for comparison with *Cerithiopsis inopinus.*)

C. inopinus has been collected from two localities only (TU 555 and TU 547). Both localities were coral reefs (possibly an extension of the same reef) and many unusual species, found nowhere else in the marls, have been taken from this limited area.

Genus BITTIUM Leach *in* Gray, 1847

Bittium LEACH *in* GRAY, 1847 (Oct.), Ann. Mag. Nat. Hist., v. 20, p. 270. Type species: *Murex reticulatus* Montagu, by subsequent designation, Gray, 1847 (Nov.)

BITTIUM SERENUM S. E. Hoerle, n. sp.

Plate 2, fig. 16

Diagnosis: Shell small and slender with three rounded nuclear whorls and seven to nine slightly rounded whorls in adult. Cancellate pattern formed on the teleoconch by four heavy spiral cords crossing numerous axial riblets, about twenty to a turn; a more slender cord lying just behind the distinct suture. Sutural cord terminating the body whorl; another cord of equal strength paralleled by three more of diminishing strength on the contracted base. Aperture broadly elliptical with a small posterior sinus and a short shallow anterior canal. Outer lip thin, nearly straight above and flaring anteriorly, not lirate within; inner lip with a band of callus and slightly reflected anteriorly. One strong varix opposite the outer lip.

Dimensions of holotype: height 4.9 mm, diameter 1.5 mm.

Holotype: USNM 646964.

Type locality: TU 546, Ten Mile Creek, about 1½ miles west of Chipola River (NW ¼ Sec. 12, T1N, R10W), Calhoun County, Florida (?=USGS 2212, "one mile west of Bailey's Ferry").

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimen: USNM 646964 (holotype). Other occurrences: TU locality nos. 70, 458, 459, 547, 554, 555, 655, 825, 951, 998, 1021.

Discussion: Bittium serenum is the only recognized member of the genus *Bittium* found to date in the Chipola marls. Its distribution is widespread: Ten Mile Creek, Farley Creek and the Chipola River; however, it is uncommon at every locality with the exception of TU 546 where over 400 specimens were collected. The sculpture of this neat little shell is remarkably stable compared to the variability of the other cerithiids from the Chipola Formation. All specimens examined have only the one strong varix, which is opposite the outer lip, and the same precise cancellate sculpture.

Genus SEILA A. Adams, 1861

Seila A. ADAMS, 1861, Ann. Mag. Nat. Hist., (Ser. 3), v. 7, p. 131. Type species: *Seila dextroversus* (Adams and Reeve) by subsequent designation, Dall, 1889.

SEILA ADAMSII (H. C. Lea)

Plate 2, fig. 17

Cerithium terebrale C. B. ADAMS, 1840, Boston Jour. Nat. Hist., v. 3, p. 320, pl. 3, fig. 7. (Not *C. terebrele* Lamarck, 1804).
Cerithium adamsii H. C. LEA, 1845, Amer. Phil. Soc., Trans., (Ser. 2), v. 9, extras p. 42.
Seila adamsii H. C. Lea. DALL, 1892, Wagner Free Inst. Sci., Trans., v. 3, pt. 2, p. 267.
Seila adamsii variety *attenuata* DALL, 1892, Wagner Free Inst. Sci., Trans., v. 3, pt. 2, p. 268.
Cerithium terebellum and *terebrale* C. B. Adams. CLENCH and TURNER, 1950, Occas. Papers on Mollusks, v. 1, no. 15, p. 349, pl. 37, figs. 5-7.

Diagnosis: Shell elongate, slender, flat-sided with three plus rounded nuclear whorls plus twelve to fourteen teleoconch whorls in adult specimens. Three elevated, flat topped, revolving cords on each whorl; interspaces equal to width of cords, bearing numerous incrementals. Body whorl with four spiral cords; aperture subquadrate; short, truncated canal bent to left; siphonal canal broad and deep. Concave base marked by growth lines only and bounded by a single, small spiral cord emerging from the aperture.

Dimensions of lectotype: height .46 inch, diameter .13 inch (Clench and Turner, 1950, p. 350).

Lectotype: Harvard MCZ 156200.

Type locality: New Bedford, Massachusetts (Clench and Turner, 1950, p. 350).

Occurrence: Chipola Formation, Florida; late lower Miocene. Pinecrest Beds, Florida; upper Miocene. Caloosahatchee Formation, Florida; Pliocene. Unnamed post-Caloosahatchee formation, Florida; Pleistocene. Recent, Massachusetts to West Indies.

Figured specimen: USNM 113318 (Lectotype—*Seila attenuata* Dall); height 5.0 mm, diameter 1.6 mm; locality USGS 2213. Other occurrences: TU locality nos. 458, 546, 547, 548, 554, 555, 825.

Discussion: Dall (1892, p. 268) mentioned that "variety *attenuata*", found in the Chipola beds, "differs from the type [*S. adamsii*] only in its smaller size and slightly more cylindrical form." Except for the above statement, which Dall made in his discussion of *S. adamsii*, no further description nor any figure is available for the species. There are two lots of fragmented specimens in the U. S. National Museum, bearing the label *S. adamsii* var. *attenuata* Dall: one lot of 33 fragments from USGS locality 2211 (lower bed, Alum Bluff), with the number USNM 114263; one lot of 28 fragments from USGS locality 2213 (one mile below Bailey's Ferry), with the number USNM 113318. As all of the specimens in both lots were part of the "original type lot" available to Dall, and as the material from USGS 2211 is in very poor condition, a specimen from USGS 2213 is here selected as lectotype (pl. 2, fig. 17), even though Schuchert and Dall (1905, p. 569) indicated that the specimens from USGS 2211 were to be considered as "cotypes."

There appears to be no significant differences in *S. adamsii* and *S. attenuata*, therefore the writer places *S. attenuata* in synonymy with *S. adamsii*. Adult specimens of *S. adamsii* may vary in height but the strength of the sprial cords, their relation to each other and to the width of the interspaces remain constant.

S. adamsii has been collected from the Chipola River and Farley Creek localities; however, only one specimen has been found on Ten Mile Creek. This species has survived since lower Miocene time and in the Recent fauna is recorded from Massachusetts to the West Indies.

Subfamily DIASTOMATINAE Crosse and Fischer, 1893

Genus ALABA H. and A. Adams, 1853

Alaba H. and A. ADAMS, 1853, Genera Recent Moll., v. 1, p. 241. Type species: *Rissoa melanura* C. B. Adams, 1850 [=*Eulima incerta* (Orb., 1842)], by subsequent designation, Nevill, 1885.

ALABA CHIPOLANA Dall

Plate 2, fig. 15

Alaba chipolana DALL, 1892, Wagner Free Inst. Sci., Trans., v. 3, pt. 2, p. 292, pl. 21, fig. 9.
Alaba chipolana Dall. GARDNER, 1947, U. S. Geol. Surv. Prof. Paper 142-H, p. 580, pl. 54, fig. 17.

Diagnosis: "Shell small, smooth, with two very minute nuclear and eight or nine subsequent well-rounded whorls; sculpture only of faint incremental lines, obscure malleations and faint varices; the varices are irregular in number, sometimes as many as three on one whorl, but they are little elevated; the penultimate varix is usually more pronounced in the adult than any of the others; aperture sub-ovate, outer lip slightly thickened inside, simple; basal part rounded, with a faint sinus at the end of the pillar; body without perceptible callus; pillar straight, slender, perceptibly axially twisted." (Dall, 1892)

Dimensions of holotype: height 6.0 mm, diameter 2.75 mm.

Holotype: USNM 113384.

Type locality: USGS 2213, one mile below Bailey's Ferry, Chipola River, Calhoun County, Florida (=TU 457).

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimen: USNM 646963; height 5.7 mm, diameter 2.8 mm; locality TU 555. Other occurrences: TU locality nos. 70, 458, 459, 546, 547, 548, 554, 820b, 821, 825, 951, 998.

Discussion: Gardner (1947, p. 580) suggested that there might be a subspecies associated with *A. chipolana*, "a somewhat smoother and more slender form." After examination of over 600 specimens from 13 localities the writer concludes the atypical forms are well within the range of variability. They have the same impressed suture, lack of spiral sculpture, one or many varices, straight pillar, thin outer lip and patulous aperture. The majority of specimens have the labrum broken back to the last varix and thus the lip appears to be "slightly thickened inside." A few adult specimens have no noticeable varices and conversely a juvenile may have six to eight. Usually there is at least one varix a short distance behind the outer lip.

Genus ALABINA Dall, 1902

Alabina DALL, 1902, Nautilus, v. 15, p. 127. Type species: *Bittium cerithidioide* Dall, by original designation.

Subgenus CALOOSALBA
Olsson and Harbison, 1953

Caloosalba OLSSON and HARBISON, 1953, Acad. Nat. Sci. Phila., Mon. 8, p. 293. Type species: *Bittium adamsii* Dall, by original designation.

ALABINA (CALOOSALBA) BOIPLEX (Dall)

Plate 2, fig. 13

Bittium (Stylifernia) boiplex DALL, 1892, Wagner Free Inst. Sci., Trans., v. 3, pt. 2, p. 275, pl. 21, fig. 14.
Aneurychilus (Alabina) boiplex (Dall). COSSMANN, 1906, Essais Paléoconch. Comp., v. 7, p. 181, pl. 12, figs. 8,9.
Obortio (Alabina) boiplex (Dall). GLIBERT, 1962, Mém. Inst. Roy. Sci. Nat. Belg., (Ser. 2) fasc. 69, p. 189.

Diagnosis: "Shell small, slender, acutely pointed, strongly sculptured, with two minute, smooth and ten subsequent rounded whorls; earlier whorls with only spiral sculpture, which later becomes sharp, elevated threads alternating in strength, with three strong spirals on the base, on the posterior of which the distinct, appressed suture is applied; the spiral sculpture crosses numerous concavely-arched riblets, which may be strong or obsolete; there are also numerous well-marked, rounded varices irregularly distributed both in position and number; the whorls are well rounded, the aperture ovate, with hardly a trace of canal; a short, arched pillar, thin, simple outer lip, and no lirations in the throat." (Dall, 1892)

Dimensions of holotype: height 8.5 mm, diameter 1.75 mm.

Holotype: USNM 113343.

Type locality: USGS 2213, one mile below Bailey's Ferry, Chipola River, Calhoun County, Florida (=TU 457).

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimen: USNM 646961; height 6.8 mm, diameter 2.0 mm; locality TU 546. Other occurrences: TU locality nos. 70, 196, 456, 457, 458, 459, 547, 548, 554, 555, 655, 787, 806, 817, 820b, 821, 823, 825, 830, 951, 998, 1020, 1021, 1048, 1050.

Discussion: A. boiplex is a most profuse member of the family Cerithiidae and is particularly abundant along Ten Mile Creek, TU 546 yielding nearly 3,000 specimens. A typical *A. boiplex* has a small nucleus of 2½ whorls and two or three angulated post-nuclear whorls, the remaining eight or nine are well rounded, with distinct sutures bordered in front and behind by a small cord. The early post-nuclear whorls have only the medial and anterior spiral cords and not the three heavy ones that are indicative of this species in the later stages. The posterior half of these early whorls are ornamented by spiral threads and it is not until the third or fourth whorl that one of the threads becomes strengthened to form a cord equalling the other two primary cords. The numerous bowed riblets extend from suture to suture and small beads are formed where they are intersected by the cords. A variable number of rounded varices may be scattered along the spire. The sculpture may be strong or faint but the distinguishing features are the three primary cords, the rounded whorls and the typical *Alabina* subcircular aperture with a mere suggestion of an anterior canal.

ALABINA (CALOOSALBA) TURBATRIX
S. E. Hoerle, n. sp.

Plate 2, figs. 8, 9

Diagnosis: Shell small and tapered with a nucleus of 2½ whorls plus eight to ten teleoconch whorls. Ten to fourteen straight axial riblets, evenly distributed on each turn; feeble on the posterior half of the whorl, stronger anteriorly, extending from suture to suture. The posterior half of each whorl flat to concave, ornamented by three to five microscopic threads; one strong cord midway on whorl forming the periphery, paralleled anteriorly by another of equal strength. In the interspace one or two spiral threads and a slightly heavier thread between the anterior spiral cord and sutural cord. Sharp tubercles formed by the intersection of axial riblets and primary spiral cords. Suture appressed and distinct. Axial riblets tending to fade on the body whorl, as do the coarse spiral threads. The last whorl rounded in profile and terminated basally by the sutural cord, paralleled by a subsutural cord. Aperture subcircular, outer lip thin and extending forward, forming a mere suggestion of an anterior canal. A few heavy varices on last two whorls only.

Dimensions of holotype: height 5.5 mm, diameter 1.9 mm.

Holotype: USNM 646956.

Paratype: USNM 646957; height 4.9 mm, diameter 1.8 mm.

Type locality: TU 546, Ten Mile Creek, about 1½ miles west of Chipola River (NW ¼ Sec. 12, T1N, R10W), Calhoun County, Florida (?=USGS 2212, "one mile west of Bailey's Ferry").

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimens: Fig. 8, USNM 646956 (holotype). Fig. 9, USNM 646957 (paratype); locality same as holotype. Other occurrences: TU locality nos. 70, 196, 458, 459, 547, 554, 555, 655, 787, 821, 825, 830, 951, 998, 1020, 1021.

Discussion: A. turbatrix is found with its congenitor *A. boiplex* but not in the same profusion, having a ratio of about 1-4. The new species is a more tapered shell than *A. boiplex* and has fewer whorls in adult specimens. The axial riblets are not arcuate as on *A. boiplex* and are feeble on the posterior half of the whorls. The heavier varices, one or several, are confined to the last two whorls only. The profile of the whorls is biangular instead of rounded. The two species of *Alabina* are closely related but the stable features of each are distinctive enough to warrant the recognition of this new species.

Family POTAMIDIDAE
H. and A. Adams, 1854

Genus POTAMIDES Brongniart, 1810

Potamides BRONGNIART, 1810, Ann. Mus. Hist. Nat. (Paris), v. 15, pp. 367-368. Type species: *Potamides lamarckii* Brongniart, by monotypy.

POTAMIDES SUPRASULCATUS (Gabb)

Plate 1, figs. 7, 8

Cerithium suprasulcatus GABB, 1873, Amer. Philos. Soc., Trans., (N. S.), v. 15, p. 237.
Potamides ormei MAURY, 1917, Bulls. Amer. Paleontology, v. 5, no. 29, p. 126, pl. 22, fig. 8.
Potamides suprasulcatus (Gabb). PILSBRY, 1922, Acad. Nat. Sci. Phila., Proc., v. 73, p. 373, pl. 29, figs. 10, 11 (holotype).
Potamides ormei var. *infraliteratus* SPEIKER, 1922, Johns Hopkins Univ., Studies in Geology, no. 3, p. 58, pl. 2, fig. 11.
Potamides infraliteratus Speiker. OLSSON, 1932, Bulls. Amer. Paleontology, v. 19, no. 68, p. 193, pl. 23, figs. 5, 12.
Potamides suprasulcatus (Gabb). WOODRING, 1959, U. S. Geol. Surv. Prof. Paper 306-B, p. 176, pl. 28, figs. 3-6.
Potamides suprasulcatus (Gabb). JUNG, 1965, Bulls. Amer. Paleontology, v. 49, no. 223, p. 490, pl. 64, figs. 11, 12.

Diagnosis: "Shell broad, spire moderately elevated, whorls numerous, increasing rapidly in width flat on the sides; suture channeled. Surface plain or marked by a few lines in advance and by a deep revolving groove a short distance below the suture. Aperture subquadrate, canal very small, no folds; outer lip strongly produced on the base, adjoining the canal. Length about 1.5 in., width .7 in." (Gabb, 1873)

Shell stout, whorls flat-sided, rapidly enlarging. Early whorls (nucleus lost) with a narrow subsutural spiral band paralleled by a broader band, and cut by numerous straight to slightly arcuate axial riblets extending from suture to suture. Both axial and spiral sculpture changing in appearance with the growth of the shell. Posterior band becoming heavier and noded by the axials; adjacent groove widening and deepening; anterior spiral band dividing medially by a narrow undulating groove; axial riblets becoming close-set strong nodes, aligning with those on the posterior spiral band in a somewhat arcuate pattern; both of the afore-mentioned grooves and the groove posterior to the narrow sutural cord overrun by tertiary threads. On later whorls, in profile, the noded subsutural band extending a little beyond the anterior spirals; the base marked by revolving cords, the cords becoming less undulatory as the axial riblets fade; the tertiary threads disappearing and only incrementals present between the basal cords. Inner and outer lips much thickened; inside of outer lip with a series of grooves corresponding in number and position to the heavy spiral cords. Aperture obliquely elliptical, the slightly ascending labrum forming a small posterior sinus. Heavily callused labium detacted from the shell anteriorly. Siphonal canal short and oblique..

Dimensions of holotype: height 29.5 mm, diameter 17.3 mm (Pilsbry, 1922, p. 374).

Holotype: ANSP 2600.

Type locality: Dominican Republic, exact locality unknown.

Occurrence: ? Tabara Formation, Dominican Republic; Oligocene . Chipola Formation, Florida; latelower Miocene. Zorritos Formation, Peru; Daule Formation, Columbia; Progresso Formation, Ecuador; unnamed formation, Venezuela; Culebra Formation, Panamá; Brasso Formation, Trinidad; Miocene.

Figured specimens: Fig. 7, USNM 646944; height (incomplete) 30.4 mm, diameter 15.4 mm, TU locality 459. Fig. 8, USNM 646945; height (incomplete) 11.0 mm, diameter 5.1 mm, TU locality 459. Other occurrences: TU locality nos. 70, 196, 548, 555, 950.

Discussion: P. suprasulcatus has a meager representation from the higher beds of Ten Mile Creek and is completely absent in the lower beds. The greatest number of specimens were taken from TU 459, a Chipola River locality. Living members of the genus *Pota-*

PLATE 2

Figures Page

1. *Hemicerithium akriton* S. E. Hoerle, n. sp. (X 2) 6
USNM 646950 (holotype); height 18.4 mm, diameter 12.3 mm.
Locality: TU 820b. Chipola Fm., lower Miocene.

2. *Hemicerithium adela* (Dall) (X 4) 7
USNM 165104 (holotype); height 9.2 mm, diameter 4.6 mm.
Locality: Ballast Point, Tampa Bay, Florida. Tampa Limestone, lower Miocene.

3. *Hemicerithium cossmanni* (Dall) (X 3) 6
USNM 646951; height 14.4 mm, diameter 6.4 mm.
Locality: TU 825. Chipola Fm., lower Miocene.

4. *Hemicerithium craticulum* S. E. Hoerle, n. sp. (X 5) 7
USNM 646952 (holotype); height 10.8 mm, diameter 3.7 mm.
Locality: TU 998. Chipola Fm., lower Miocene.

5. *Hemicerithium pagodum* S. E. Hoerle, n. sp. (X 8) 7
USNM 646953 (holotype); height 8.5 mm, diameter 3.2 mm.
Locality: TU 825. Chipola Fm., lower Miocene.

6, 7. *Tenuicerithium chipolanum* (Dall) 10
6. (X 4) USNM 646954; height 14.4 mm, diameter 5.0 mm.
Locality: TU 825. Chipola Fm., lower Miocene.
7. (X 4) USNM 646955; height 13.6 mm, diameter 4.4 mm.
Locality: TU 825. Chipola Fm., lower Miocene.

8, 9. *Alabina (Caloosalba) turbatrix* S. E. Hoerle, n. sp. 16
8. (X 8) USNM 646956 (holotype); height 5.5 mm, diameter 1.9 mm.
Locality: TU 546. Chipola Fm., lower Miocene.
9. (X 8) USNM 646957 (paratype); height 4.9 mm, diameter 1.8 mm.
Locality: TU 546. Chipola Fm., lower Miocene.

10. *Tenuicerithium absonum* S. E. Hoerle, n. sp. (X 4) 11
USNM 646958 (holotype); height 13.2 mm, diameter 4.8 mm.
Locality: TU 555. Chipola Fm., lower Miocene.

11. *Tenuicerithium ascensum* S. E. Hoerle, n. sp. (X 5) 11
USNM 646959 (holotype); height 9.7 mm, diameter 3.9 mm.
Locality: TU 459. Chipola Fm., lower Miocene.

(continued next page)

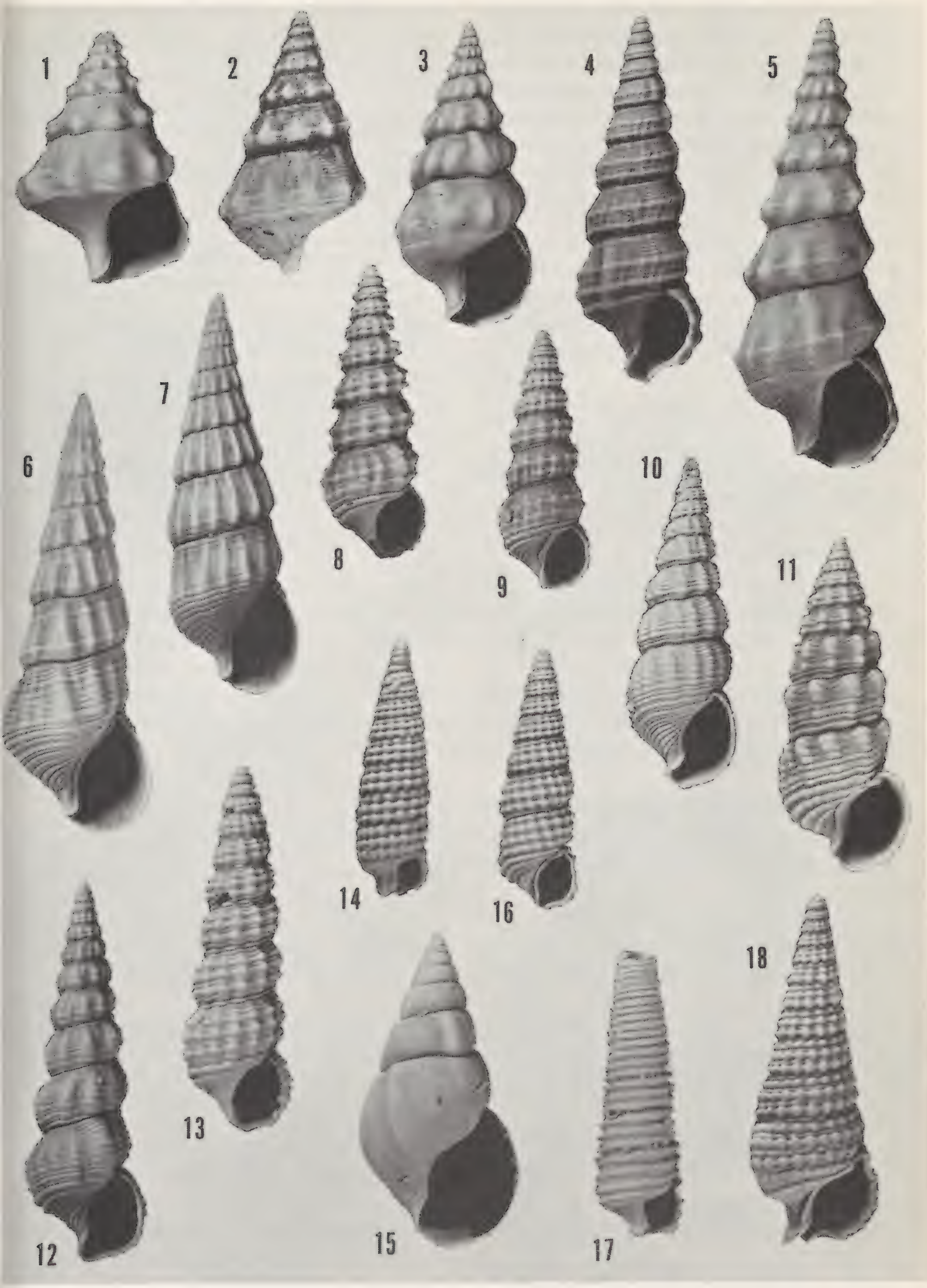

PLATE 2

mides are habitants of brackish water. Accompanying fauna from TU 459 show a marked degree of corrosion, which tends to bear out the premise that this locality was an estuary. *P. suprasulcatus* is a widespread species, although not necessarily abundant at any one locality. It has been found in Panamá, Santo Domingo and parts of northern South America. The occurrence of this species in the Chipola Formation is its first recorded appearance in Florida. Jung (1965, p. 490) gave ANSP 1314 as the number of the holotype. This is in error, as the number he cited belongs with the type of *P. roumaini* Pilsbry.

Genus TEREBRALIA Swainson, 1840

Terebralia SWAINSON, 1840, Treat. Malac., p. 315.
Type species: *Strombus palustris* Linné, by subsequent designation, Sacco, 1895.

TEREBRALIA DENTILABRIS (Gabb)

Plate 1, Figs. 9-11

Cerithium dentilabre GABB, 1873, Amer. Philos. Soc., Trans., (N. S.), v. 15, p. 237.
Pyrazisinus harrisi MAURY, 1902, Bulls. Amer. Paleontology, v. 3, no. 15, p. 376, pl. 28, figs. 2, 2a.
Potamides dentilabrum Gabb. MAURY, 1917, Bulls. Amer. Paleontology, v. 5, no. 29, pt. 1, p. 126.
Potamides dentilabris (Gabb). PILSBRY, 1922, Acad. Nat. Sci. Phila., Proc., v. 73, p. 374, pl. 29, figs. 6, 7.
Terebralia dentilabris (Gabb)?. WOODRING, 1959, Geol. Surv. Prof. Paper 306-B, p. 178.

Diagnosis: "Shell large, heavy, spire elevated, suture distinct, whorls flattened on the sides, bearing a few very faint varices. Surface marked by not very strong longitudinal ribs or undulations; these are crossed by four or five strong revolving ribs, flat on top and with concave interspaces, giving the surface

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12. *Tenuicerithium permutabile* (Dall) (X 4) 10
USNM 646960; height 12.6 mm, diameter 3.8 mm.
Locality: TU 546. Chipola Fm., lower Miocene.

13. *Alabina (Caloosalba) boiplex* (Dall) (X 8) 16
USNM 646961; height 6.8 mm, diameter 2.0 mm.
Locality: TU 546. Chipola Fm., lower Miocene.

14. *Cerithiopsis inopinus* S. E. Hoerle, n. sp. (X 10) 13
USNM 646962 (holotype); height 4.0 mm, diameter 1.3 mm.
Locality: TU 555. Chipola Fm., lower Miocene.

15. *Alaba chipolana* Dall (X 8) 15
USNM 646963; height 5.7 mm, diameter 2.8 mm.
Locality: TU 555. Chipola Fm., lower Miocene.

16. *Bittium serenum* S. E. Hoerle, n. sp. (X 8) 14
USNM 646964 (holotype); height 4.9 mm, diameter 1.5 mm.
Locality: TU 546. Chipola Fm., lower Miocene.

17. *Seila adamsii* (H. C. Lea) (X 8) 14
USNM 113318 (lectotype-*Seila adamsii* var. *attenuata* Dall); height 5.0 mm, diameter 1.6 mm.
Locality: USGS 2213. Chipola Fm., lower Miocene.

18. *Rhinoclavis ogilvies* (Maury) (X 4) 13
USNM 646973; height 12.6 mm, diameter 5.0 mm.
Locality: TU 91. Oak Grove Sand, lower Miocene.

a coarse but pretty regular cancellate appearance. Aperture sub-quadrate, with two strong folds on the columella, one in the middle, the other behind; outer lip with one large tubercular tooth in the middle and one in advance. These folds and teeth are absent in the young shell." (Gabb, 1873)

Dimensions of holotype: height 49.5 mm, diameter 21.0 mm (Pilsbry, 1922, p. 374).

Holotype: ANSP 2502.

Type locality: Dominican Republic, exact locality unknown.

Occurrence: Culebra Formation, Panamá; early Miocene. Chipola Formation, Florida; late lower Miocene. Unknown formation, Dominican Republic; Miocene.

Figured specimens: Fig. 9, USNM 646946; height 16.7 mm, diameter 7.6 mm. Fig. 10, USNM 646947; height 49.0 mm, diameter 21.6 mm. Fig. 11, USNM 646948; height 53.7 mm, diameter 23.5 mm; locality TU 459. Other occurrences: TU locality nos. 458, 547, 548, 555.

Discussion: The nucleus is lost on all specimens of *T. dentilabris* examined by the writer. The early post-nuclear whorls have axial ornamentation only. With the growth of the shell four equal-width broad, band-like spiral cords, separated by channeled grooves, gradually appear on the whorls, the posterior band the first to be marked off. One small, smooth, spiral cord lies posteriorly to the deeply indented suture. The basal portion of the flaring outer lip is produced to the left and meets the columella to form an enclosed circular anterior canal. Specimens with perfect apertures can easily be mistaken for *Pyrazisinus* as was demonstrated by Maury (1902, p. 376). The strong plaits on the columella and the internal nodes at each heavy varix are not visible if the aperture is complete. Many specimens are broken back to the last varix, which is usually opposite the outer lip, and only then can the armature be seen.

The majority of specimens examined show a degree of erosion on the early whorls. The genus *Terebralia* of the Recent lives in estuaries and lagoons where the water is brackish. The matrix at locality TU 459 from where the greatest number of specimens were collected, is mainly comprised of a gravelly material and nearly all of the associated fauna have a tumbled beachworn appearance. This suggests a shoreline or the mouth of a river. The geographic range for this species along the Chipola River is less than one mile and no specimens are known from localities other than this limited area. There are no Recent species of *Terebralia* from the western Atlantic or Caribbean waters. The fossil specimens from the Chipola Formation are the first representatives of this genus in the southeastern United States.

V. LOCALITY DATA

The following are Tulane University fossil localities. Except as noted all are in the Chipola Formation, Calhoun County, Florida.

70. Ten Mile Creek, at bridge of Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W).
91. Oak Grove Sand, (type locality), west bank of Yellow River, about 100 yards below bridge at Oak Grove, (NE ¼ Sec. 20, T5N, R23W), Okaloosa Co., Florida.
196. Ten Mile Creek, about ¼ mile upstream from bridge of Florida Highway 73 (NE ¼ Sec. 11, T1N, R10W).
453. Alum Bluff (lower beds), Apalachicola River (NE ¼ Sec. 24, T1N, R8W), Liberty Co., Florida.
456. Ten Mile Creek, about ¼ mile downstream from bridge of Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W).
457. West bank of Chipola River, about ½ mile below Ten Mile Creek (SW ¼ Sec. 17, T1N, R9W).
458. East bank of Chipola River, above Farley Creek (SW ¼ Sec. 20, T1N, R9W).
459. East bank of Chipola River, steep bank about 1500 feet above the mouth of Taylor Lake Branch (NW ¼ Sec. 29, T1N, R9W).
546. Ten Mile Creek, about 1½ miles west of Chipola River (NW ¼ Sec. 12, T1N, R10W).
547. West bank of Chipola River, about 2000 ft. above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W).
548. West bank of Chipola River (NW ¼ Sec. 29, T1N, R9W).
549. East bank of Chipola River, about ¼ mile below Four Mile Creek (NE ¼ Sec. 32, T1N, R9W).
554. East bank of Chipola River at power line crossing (SW ¼ Sec. 17, T1N, R9W).
555. East bank of Chipola River, about 1000 ft. above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W).
655. Ten Mile Creek, about 0.1 mile downstream from bridge of Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W).
711. West bank of Chipola River, about ¼ mile up from mouth of Farley Creek (SW ¼ Sec. 20, T1N, R9W).

787. Ten Mile Creek, south bank about 1½ miles west of Chipola River (SE ¼ Sec. 12, T1N, R10W),
806. West bank of Chipola River, about one mile below power line crossing (NW ¼ Sec. 20, T1N, R10W).
817. South side of Ten Mile Creek, large gully on the property of Mr. A. Sexton (1967) (SE ¼ Sec. 12, T1N, R10W).
818. Farley Creek, 0.1 mile west of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W).
820b. Farley Creek (lower beds), at bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W).
821. Farley Creek, 0.1 mile east of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W).
823. Farley Creek, south bank about 2000 ft. east of bridge on Florida Highway 275 (SE ¼ Sec. 21, T1N, R9W).
825. Farley Creek at abandoned mill about ¼ mile west of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W).
826. Farley Creek, about 0.1 mile west of abandoned mill which is ¼ mile west of bridge of Florida Highway 275 (on section line between Sec. 20 & 21, T1N, R9W).
827. Farley Creek, about ½ mile west of bridge of Florida Highway 275 (SE ¼ Sec. 20, T1N, R9W).
828. Farley Creek, just upstream from mouth of unnamed tributary about 3/4 mile downstream from bridge of Florida Highway 275 (SE ¼ Sec. 20, T1N, R9W).
830. Ten Mile Creek, at power line crossing about one mile west of Chipola River (SE ¼ Sec. 12, T1N, R10W).
950. Chipola River, west bank about 2000 ft. above Farley Creek (SW ¼ Sec. 20, T1N, R9W).
951. Ten Mile Creek, about 1¼ miles west of Chipola River (SE ¼ Sec. 12, T1N, R10W).
998. Ten Mile Creek, about 1¼ miles west of Chipola River (SE ¼ Sec. 12, T1N, R10W).
999. Farley Creek, about 1000 yds. downstream from bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W).
1019. East bank Chipola River, about 2000 ft. downstream from power line crossing (NW ¼ Sec. 20, T1N, R9W).
1020. Small tributary (not shown on USGS topographic map) on east bank of Chipola River about ½ mile below power line crossing (NE ¼ Sec. 20, T1N, R9W).
1021. Ten Mile Creek, north bank, about 2200 ft. east of bridge on Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W).
1048. Farley Creek, south bank, about 0.8 mile east of bridge on Florida Highway 275 (NE ¼ Sec. 21, T1N, R9W).
1049. Farley Creek, south bank, about 1.0 mile east of bridge on Florida Highway 275 (NE ¼ Sec. 21, T1N, R9W).
1050. West bank of Chipola River at power line crossing (SW ¼ Sec. 17, T1N, R9W).

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NOTES ON THE FAUNA OF THE CHIPOLA FORMATION – IV

A NEW SPECIES OF *NERITOPSIS* (MOLLUSCA: GASTROPODA)

ROBERT C. HOERLE
WEST PALM BEACH, FLORIDA

Collections from the Chipola Formation made by the writer and friends at two localities along the Chipola River were found to contain rare specimens of *Neritopsis*, an unusual genus heretofore unknown in the New World. This genus apparently originated in Europe during the Mesozoic Era and attained its maximum development in the Jurassic Period, assuming many forms of ornamentation. Cossmann (1925, p. 89) stated that "formes sillonnées, formes treillissées, formes variqueuses et épineuses, à côtes écartées" all occur at the same time, showing the extreme initial variability of this genus. However, by the end of the Cretaceous Period the sculpture had more or less stabilized to that of granulated spiral cords. In addition to the shells, workers have based taxa on the calcareous, trapezoidal opercula, which also occur in the fossil state.

The advent of the Eocene epoch resulted in a marked decline in the number of *Neritopsis* species. Prior to the Eocene over fifty species had been described but, according to Cossmann, investigation of European Eocene beds have yielded only six species: *N. parisiensis* Deshayes; *N. acutispira* Cossmann; *N. pustulosa* Bellardi; *N. vidali* Doncieux; *N. agassizi* Bayan; and *N. radulaeformis* Oppenheim. Differences in strength of the granulations on the spiral cords, width of interspaces, height of spires, and overall size of adult specimens are the characters used for the separation of these species. There are no recorded Oligocene forms. *N. radulaeformis* Oppenheim from Monte Grumi was originally considered to be of Oligocene age, but the Priabonian beds, formerly considered Oligocene, have been reassigned to the upper Eocene. Another species, described as *Neritopsis lorioli* Cossmann and Lambert, from the Oligocene is actually a *Nerita*. The Miocene forms are *N. moniliformis* Grateloup, *N. subpustulosa* Sacco and perhaps another as yet unnamed species. Some workers feel that these latter species are so similar that the genus is represented in the Miocene by but a single variable species.

The genus has disappeared from the European area since Miocene time and the only known Recent species, *N. radula* (Linné), is uncommon in the Indo-Pacific region. It should be noted that although Cossmann (1925) gave the genotype as *N. radula* (Linné) this is incorrect, as the original description by Grateloup included only the fossil species *N. moniliformis*, making it type by monotypy. The figure of *N. radula* used by Wenz (1938, p. 412, fig. 1001) and copied in the *Treatise on Invertebrate Paleontology* (v. I) is decidedly inaccurate as it does not show the peculiar apertural notch, which is the important distinguishing morphological feature of the genus.

The Recent *Neritopsis* is a coral reef dweller in the tropical Indo-Pacific seas. The type locality of the new species from the Chipola Formation was also at the time a coral reef. However, it cannot be assumed as a scientific fact that the Old World fossil species required a similar habitat. Nevertheless, geological changes in the Old World resulted in migration of the genus to other areas, relocations involving thousands of miles distance and not explainable by the theory of "ocean basin spreading" or other types of continental drift. Perhaps the most reasonable explanation of this problem is that of larval drifting as advanced by Vokes (1965, p. 206). *Neritopsis* being a warm water, shallow dwelling, primitive marine gastropod with larvae capable of remaining pelagic for long periods of time, might have migrated in this manner.

Order ARCHEOGASTROPODA Thiele, 1931

Superfamily NERITACEA Rafinesque, 1815

Family NERITOSIDAE Gray, 1847

Subfamily NERITOPSINAE Gray, 1847

Genus NERITOPSIS Grateloup, 1832

Neritopsis GRATELOUP, 1832, Actes Soc. Linn. Bordeaux, v. 5, p. 129; [1847] Conchyl. Foss. Bassin Adour, Neritines, pl. 1 [pl. 5], figs. 36-38. Type species: *Neritopsis moniliformis* Grateloup, by monotypy, [= *Radula* Gray, 1842; and (based on opercula) *Peltarion* Deslongchamps and

Deslongchamps, 1858; *Cyclidia* and *Scaphandia* Rolle, 1862; *Rhynchidia* Laube, 1868].

NERITOPSIS VOKESORUM
R. C. Hoerle, n.sp.
Text figure 1

Diagnosis: Shell heavy, globose. Nucleus of about one and one-half smooth whorls; three and one-half rapidly enlarging post-nuclear whorls in adult. Seventeen to nineteen finely beaded, narrow, spiral cords cover the entire shell, commencing immediately with the first post-nuclear whorl. Wide interspaces between spiral ribs, ornamented by scabrous incrementals. Aperture circular; outer lip sharp, crenulated by spiral ribs, thickened interiorly and with numerous short lirations. Inner lip heavily calloused with an elongated excavation in central area. Slight suggestion of an umbilicus.

Dimensions of holotype: height 14.0 mm, diameter 12.8 mm.

Holotype: USNM 646934.

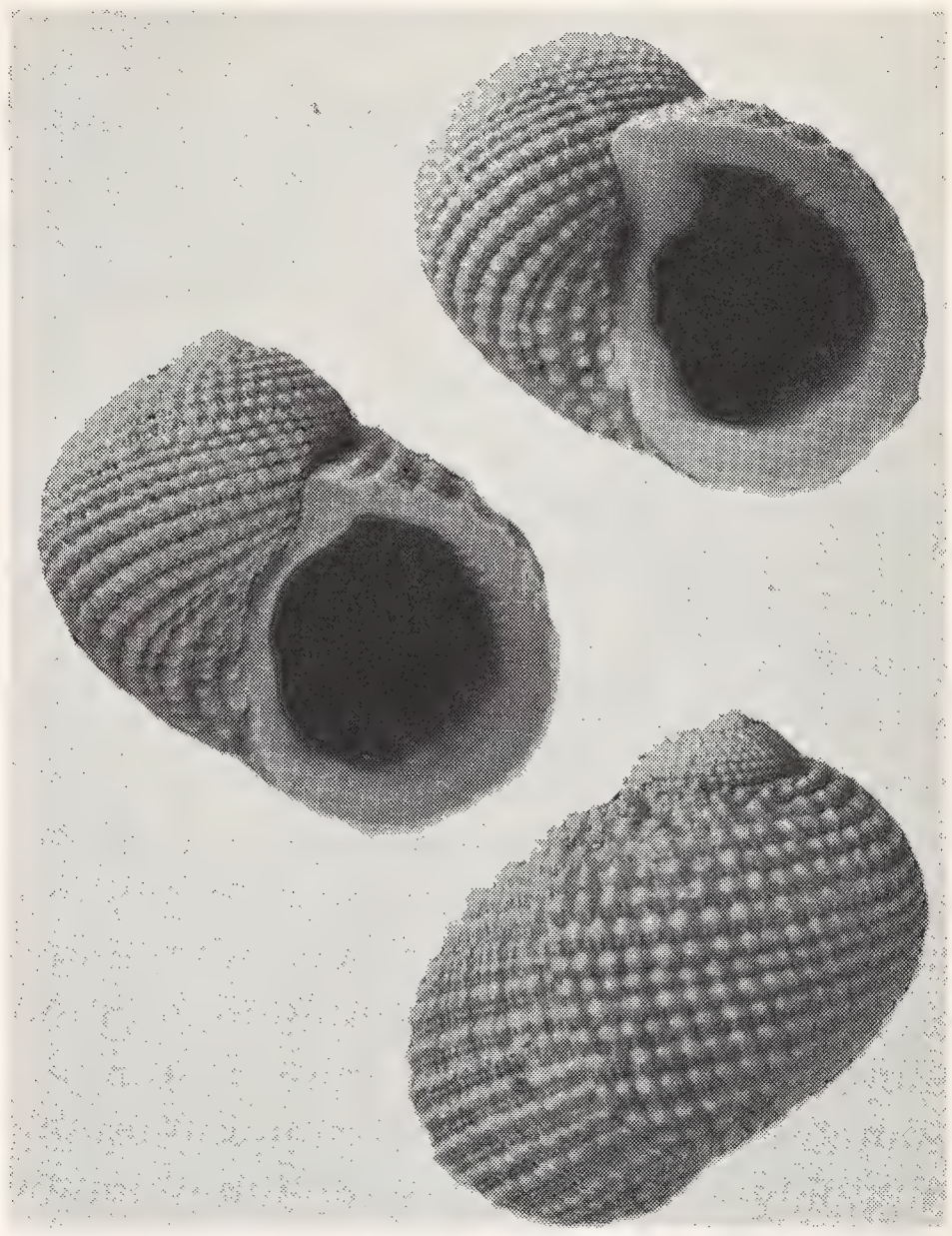
Type locality: TU 555, east bank of Chipola River, about 1000 feet above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun County, Florida.

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimen: USNM 646934 (holotype). Other occurrence: TU locality no. 547.

Discussion: Neritopsis vokesorum shows a greater affinity to *N. moniliformis* Grateloup than to the Recent species *N. radula* (Linné). The resemblance of *N. monilformis* to *N. radula* has led numerous authors in the past to synonymize the two species but other authors have disagreed. Recently Seiber (1958, p. 128) referred the Tortonian form to *N. radula* but Glibert (1962, p. 96) stated that a clear separation of the two species was evident, basing his conclusion on the wider interspaces between the beaded spiral cords on the fossil species. The writer concurs with Glibert's observation.

The first representative of the genus *Neritopsis* in the New World, although closely related to the Old World fossil species, is distinguished from *N. moniliformis* by the beading being more closely set on the spiral cords and by the slight umbilicus. Several criteria distinguish *N. vokesorum* from *N. radula*. Specimens of *N. vokesorum* have consistently higher spires. The more finely beaded spiral cords are narrower, with this ornamentation commencing on the first post-nuclear whorl, as opposed to the smooth spiral cords on the corresponding whorl of *N. radula*. Also, the interspaces are wider on *N.*



Text figure 1. *Neritopsis vokesorum* R. C. Hoerle, n. sp. USNM 646934 (holotype), X 2½.

vokesorum than on the Recent species and the former shows a tendency to form an umbilicus resulting in decreased callus in the parietal area.

This species is named for Drs. Harold E. and Emily H. Vokes of the Department of Geology, Tulane University, to whom the writer is indebted for their constant encouragement, patience and understanding. Without their valuable assistance this contribution would not have been possible.

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November 28, 1972

NOTES ON THE FAUNA OF THE CHIPOLA FORMATION – V

SYMBIANGIA, A NEW RHIZANGIID CORAL

JOHN W. WELLS
DEPARTMENT OF GEOLOGICAL SCIENCES
CORNELL UNIVERSITY

Many years ago the late T. Wayland Vaughan described in manuscript a new genus and species of small coral from the Chipola Formation at the Baileys Ferry locality (USGS Loc. 2564=TU 457). Unfortunately, this manuscript, which exists only in preliminary draft, was never published. In 1919 (p. 219) he referred to the coral fauna of the Chipola briefly as follows:

"[It] is small: comprising four species representing as many genera, namely, *Stylophora, Antillia,* a new species that resembles *Thysanus* with a sipunculid worm in its base, and *Goniopora.*"

At least two other hermatypic genera are present in the Chipola: *Porites,* and *Montastrea cavernosa* (Linn.) var. *cylindrica* (Duncan). The undescribed species of *Antillia* mentioned by Vaughan is referable to *Antillophyllia* Vaughan, which is a junior synonym of *Trachyphyllia* Milne Edwards & Haime.

The occurrence of the little coral described here, in abundance at a number of localities in the Chipola Formation was brought to the attention of the writer by H.E. and E.H. Vokes, to whom he is indebted for the opportunity of preparing the present note.

Order SCLERACTINIA

Sub-Order FAVIINA

Family RHIZANGIIDAE

Genus SYMBIANGIA Wells, n.gen.

(The generic name proposed by Dr. Vaughan in his manuscript is preoccupied, hence cannot be resurrected).

Type species: Symbiangia vaughani (Weisbord, 1971); Miocene (Chipola Formation), Florida.

Diagnosis: Rhizangiid (astrangiid) corals, forming small, subplocoid or cerioid colonies by extratentacular budding, encrusting dead shells of small gastropods inhabited by sipunculid worms, as in *Heteropsammia, Heterocyathus,* etc. Corallites low, broader than high, strongly costate. Septa in at least three cycles, all sparsely and coarsely dentate and laterally sharply spinulose. Columella trabecular, weakly developed. Endotheca not developed.

Discussion: Symbiangia groups with other rhizangiid genera such as *Phyllangia* and *Colangia,* which have relatively few, uncrowded, weakly dentate septa, but differs from all genera of the family by its constant encrusting investment of gastropod shells occupied by sipunculids. Recognition of *Symbiangia* adds another scleractinian family to the short list of corals with symbiotic worms.

The symbiosis of small corals with sipunculids *(Aspidosiphon)* is well known. Several genera are characterized by this association which appears to be an obligate condition, as corals of these genera are not found without their companions: *Heterocyathus* (Caryophylliidae), *Heteropsammia, Psammoseris,* and *Wadeopsammia* (Dendrophylliidae). The most recent discussion of this symbiosis is that of Goreau and Yonge (1968), based on *in situ* observations of *Heteropsammia* on the Great Barrier Reefs. The activity of the *Aspidosiphon* appears to stabilize the coral on an unstable mud-sand bottom and shift the coral, which derives most of its food from the mud and sand, from place to place. Corals turned over are quickly righted by the worm as it seeks to work back into the bottom.

SYMBIANGIA VAUGHANI (Weisbord)

Plate 1, figures 1-10

Thysanus vaughani WEISBORD, 1971, Florida Bur. Geol., Bull. 53, p. 22, pl. 5, figs. 3-5; pl. 6, figs. 1-3.

Diagnosis. Having the characters of the genus as analyzed above. Calices of mature corallites are circular to subpolygonal, shallow, averaging 4 mm in diameter, to a maximum of 4.5 mm. Septa in three cycles, arranged 6/6/12, those of the third cycle uniting with the six of the second cycle. Those of the first cycle commonly with prominent pali-like inner-

most teeth surrounding the low, weak, trabecular columella. Other teeth lower, 2-3 between the paliform tooth and thin corallite wall. Costae prominent, corresponding to all septa, alternating in size, coarsely granulated.

Figured specimens: USNM 171258-171261. Collections studies: TU locality nos. 70, 430, 457 (= USGS loc. 2564), 458, 554, 655, 817, 823, 824, 827, 830, 787, 950, 1020 (all Chipola Formation, Calhoun County, Florida.)

Discussion: The size attained by the small colonies is correlated with the size of the dead gastropod shell, already inhabited by the sipunculid before settling of the coral planula. Many specimens have only 2 or 3 calices with corallites completely investing the shell. The largest observed, which incompletely encrusts a shell of *Terebra (Paraterebra) odopoia* Gardner (Pl. 1, figs. 3, 4), has 14 calices and still retains traces of the pale pink color often seen in the skeleton of living *Phyllangia dispersa* from Panamá.

One specimen (Pl. 1, fig. 7) is aberrant in that, instead of having five distinct calices normally expected from extratentacular budding, it has five petaloid septate expansions around the encrusted gastropod, each representing the site of a polyp stomodaeum resulting from intratentacular budding from a central stomodaeum.

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PLATE 1

SYMBIANGIA VAUGHANI (Weisbord)

Figures

1. USNM 171259—calicular aspect (X 4).
   Locality: TU 458. Chipola Formation.

2. USNM 171260—basal aspect, showing aperture of sipunculid tube (X 4).
   Locality: TU 458. Chipola Formation.

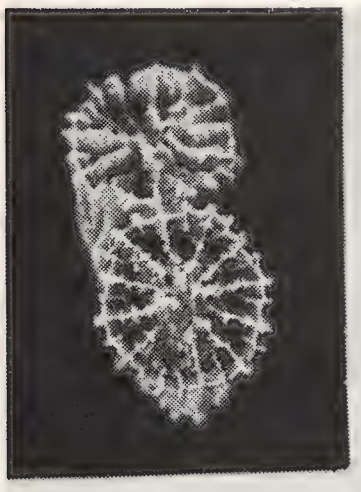
3, 4. USNM 171262—large colony partially covering shell of *Terebra (Paraterebra) odopoia* (X 2).
   Locality: TU 70. Chipola Formation.

5, 8. USNM 171258—calicular aspect (fig. 5, X 4; fig. 8, X 10).
   Locality: TU 458. Chipola Formation.

6, 10. USNM 171261—Fig. 6—vertical fracture of corallum with two calices, showing investment by coral of gastropod inhabited by sipunculid (X 10). Fig. 10—basal aspect of other half of Fig. 6, showing aperture of sipunculid tube (X 10).
   Locality: TU 458. Chipola Formation.

7. USNM 171264—aberrant corallum with 5 centers developed intratentacularly (X 4).
   Locality: TU 430. Chipola Formation.

9. USNM 171263—corallum with 10 calices (X 4).
   Locality: TU 457. Chipola Formation.



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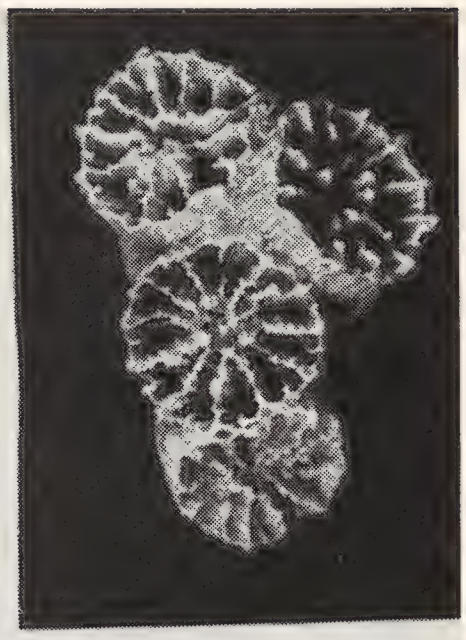

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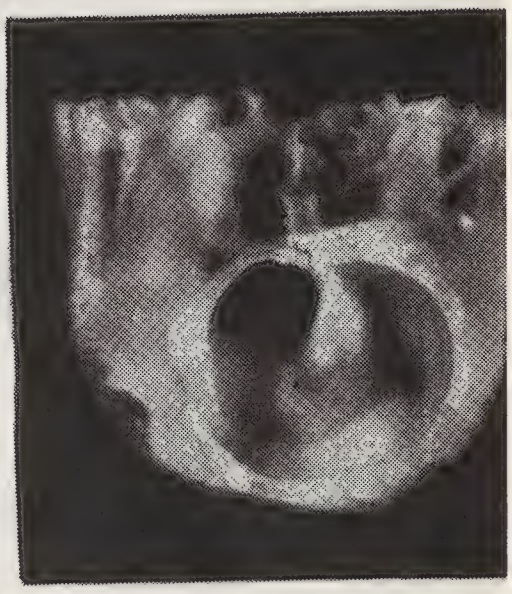

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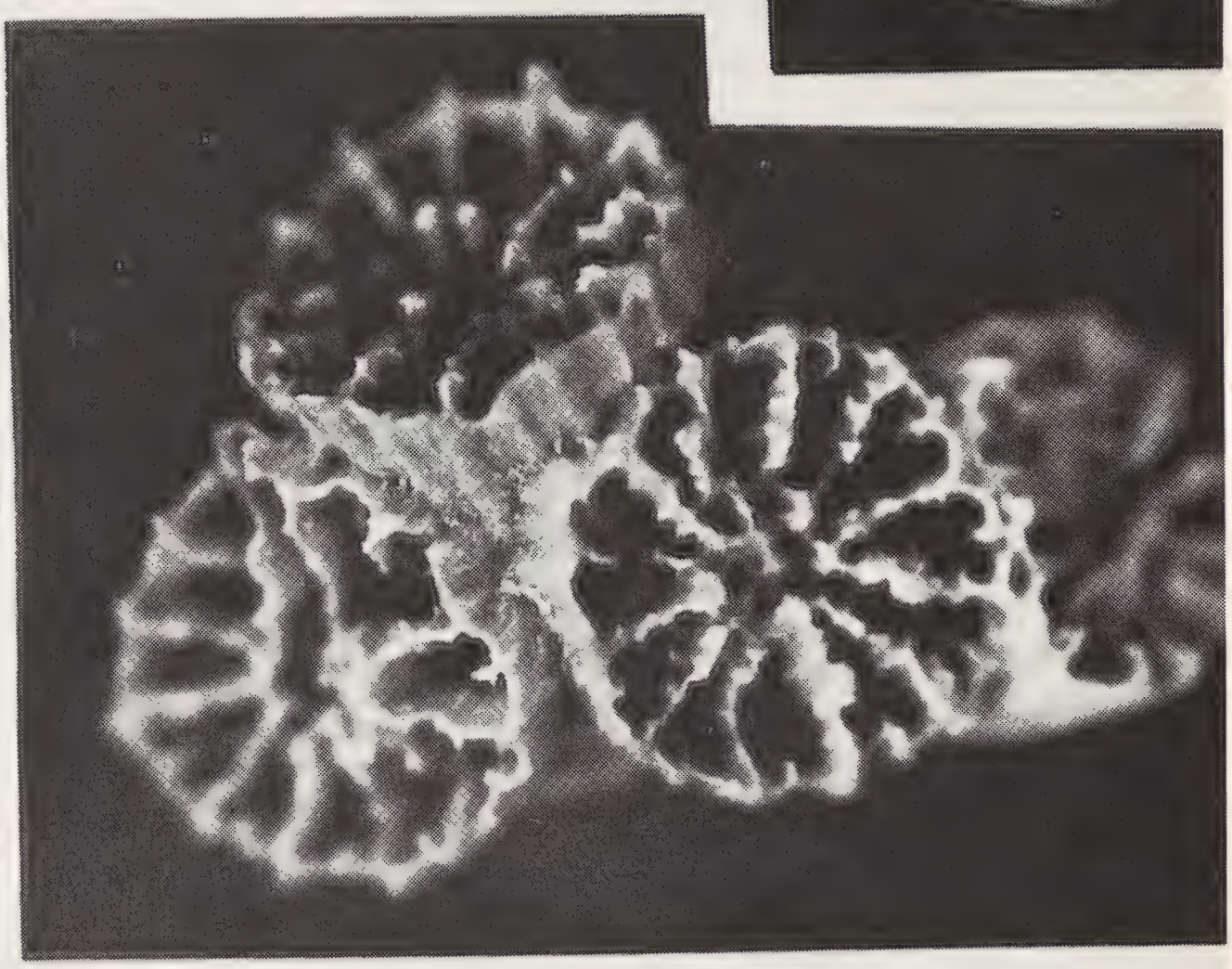

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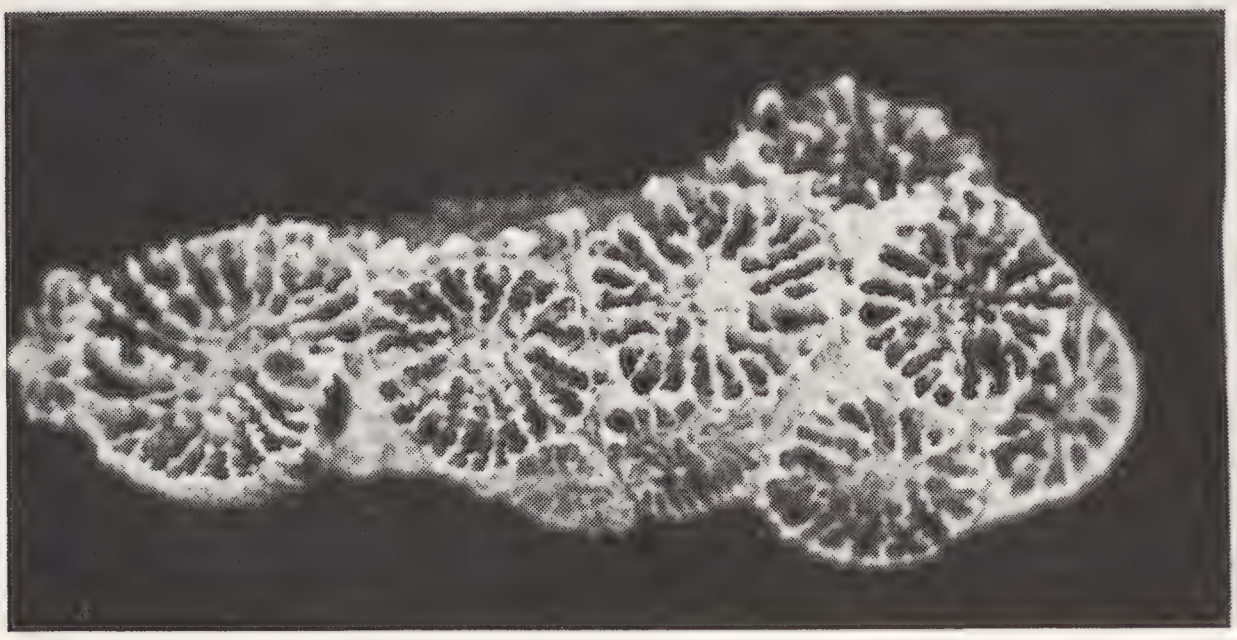

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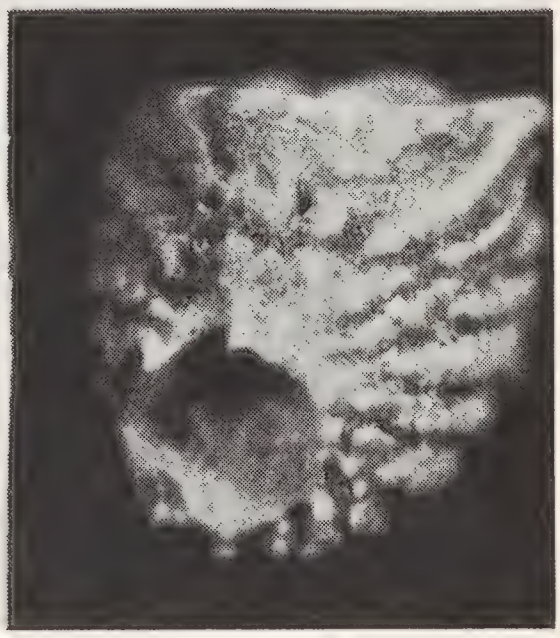

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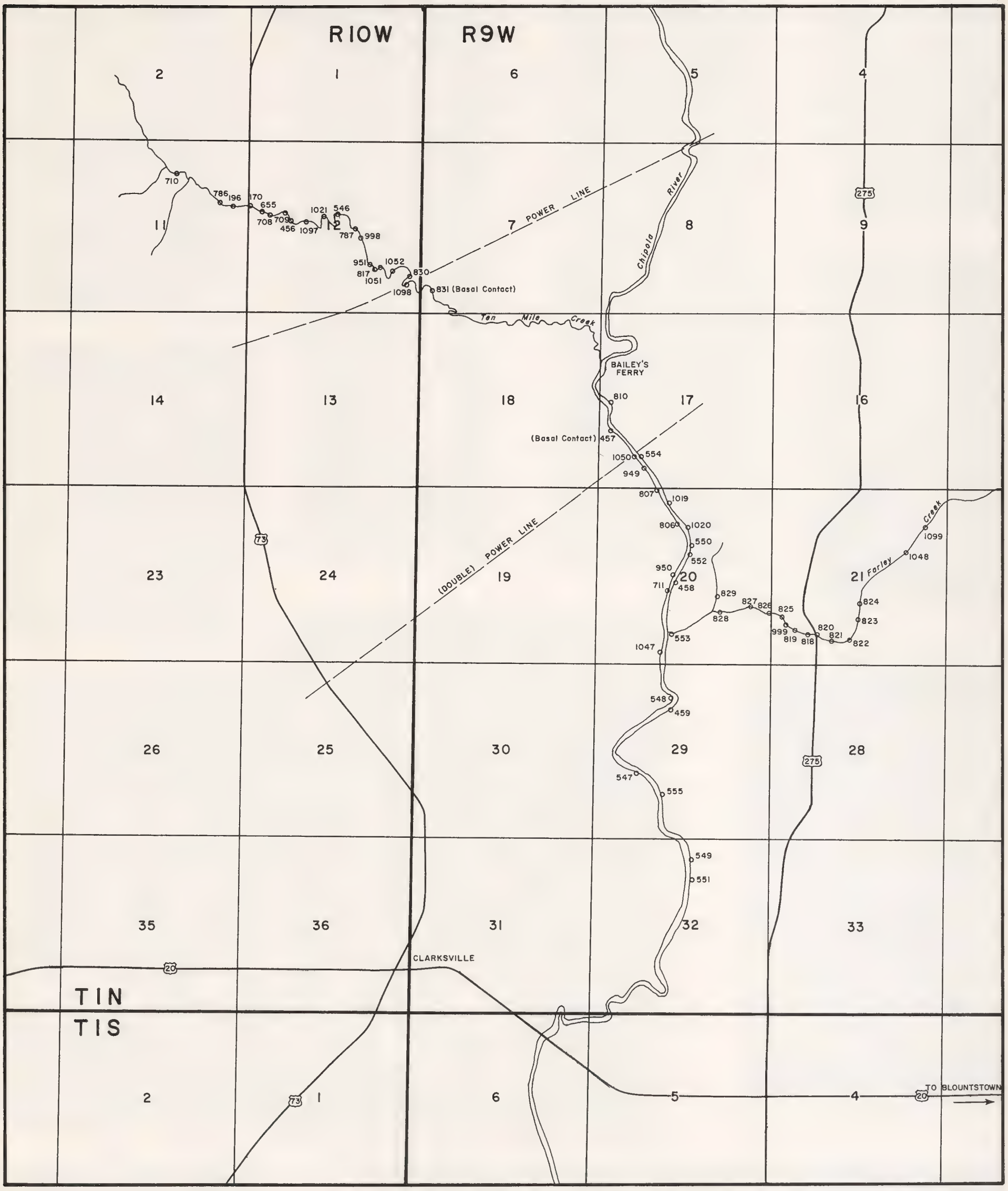
PLATE 1



Tulane University fossil localities in the vicinity of the type locality of the Chipola Formation, Calhoun County, Florida. Map based on U.S.G.S. topographic maps – Clarksville and Altha West Quadrangles.

NOTES ON THE FAUNA OF THE CHIPOLA FORMATION – VI

ON THE OCCURRENCE OF *PTERYNOTUS PINNATUS* (GASTROPODA: MURICIDAE), AND THE PROBLEMS OF DISPERSAL

EMILY H. VOKES
TULANE UNIVERSITY

This short note is solely to record the unlikely occurrence, in the Chipola Formation, of a single specimen that can be referred only to the otherwise Indo-Pacific species *Pterynotus pinnatus* (Swainson). (Actually the valid species name is *alatus* Röding, 1798. However, an appeal to the International Commission on Zoological Nomenclature to conserve the well-known species name *pinnatus,* in place of the older objective synonym *alatus*, is pending. Prior to 1960 the taxon *Purpura alatus* Röding, 1798, was used only as a synonym of *Murex pinnatus* Swainson, 1822, because it was thought to be pre-occupied by *Murex alatus* Gmelin, 1791. However, it is no longer so considered and thus has become available to replace the commonly used *"Murex" pinnatus.* By any definition *Purpura alatus* should be considered a *nomen oblitum* and thus it seems unwise to introduce it into the literature until a final decision as to its status is reached by the Commission.)

By whatever name it is called, the discovery in the Chipola Formation of the specimen here figured is noteworthy. Collected at TU 830 by that extraordinary collector Robert C. Hoerle, of West Palm Beach, Florida, it is appropriate that this note should accompany a paper by Mr. Hoerle on the occurrence in the Chipola of another otherwise Indo-Pacific form, *Neritopsis.* As has been noted on previous occasions, the Chipola Formation is fraught with unusual species, but these two Indo-Pacific forms are especially remarkable. With the exception of the Chipola occurrences here reported, neither is otherwise known in the New World, either fossil or Recent. (There are other species of *Pterynotus* in the New World but they are totally unlike *P. pinnatus,* being extremely smooth on the shell surface.)

As is also the case in *Neritopsis,* the nearest approximately contemporaneous relative to *P. pinnatus* is to be found in the Aquitaine Basin of France. *"Murex" granuliferus* Grateloup, from the classic locality of Saubriges, near Dax, is most nearly akin to our species, differing primarily in having a completely straight siphonal canal in contrast to the definitely recurved canal of *P. pinnatus.* The beds at Saubriges, formerly thought to be Tortonian, are now considered on the basis of planktonic foraminifera to be basal Langhian in age (Szots, 1968, p. 303), or just a bit younger than the Chipola (see Akers, 1972, fig. 3). Other muricine forms in common between the Chipola and the Aquitaine area were discussed by the writer in a previous paper (Vokes, 1965) and it was suggested then that the similarities formed a basis for correlation between the Chipola and the Helvetian of Aquitaine. However, more recent work on the planktonic foraminifera (Akers, 1972, p. 10) has convincingly disproved this hypothesis.

The extreme simliarities of fauna between the two disjunct areas is more likely a function of facies kinship than it is of precise time correlation. Both the Chipola and the Aquitaine faunas are truly tropical, much more so than any other found in the southern United States. On the basis of planktonic foraminifera, which to this writer are the first true inter-continental correlators, the Chipola is somewhat older than the formations of the Aquitane Basin that carry the similar fauna.

Nevertheless the similarities of fauna cannot be attributed solely to facies. There must have been some communication between the two areas. The species are too much alike, and too much unlike the preceding Paleogene ancestors for their similarities to be attributable to parallel evolution *in situ.* It is probable that some species developed in Florida (or at least in the New World) and moved across to Aquitaine and others evolved in southern Europe and moved across to Florida.

The problems of communication between these two areas cannot be ignored. One can only wonder at the means of dispersal for these shallow-water, tropical animals which, in the Recent at least, have no pelagic larval stage. The Indo-Pacific dispersal is perhaps less of a problem, for the remnants of the Tethyan Sea survived long enough to permit

free movement from the Aquitaine Basin into that region. However, this does not help explain how *P. pinnatus* made its way from Florida to its upper Miocene first appearance in the Pacific without leaving a trace of its passing through Europe. A direct trans-Pacific route is highly unlikely but by Miocene time not even the most dedicated "plate-tectonist" would suggest that the Atlantic Ocean did not exist. And yet for the numerous species that are so markedly alike between the Chipola and the Aquitaine area there almost has to be some explanation besides random "rafting" via floating debris. The writer can offer no positive suggestions as to the means of dispersal, but can only call attention to the problem.

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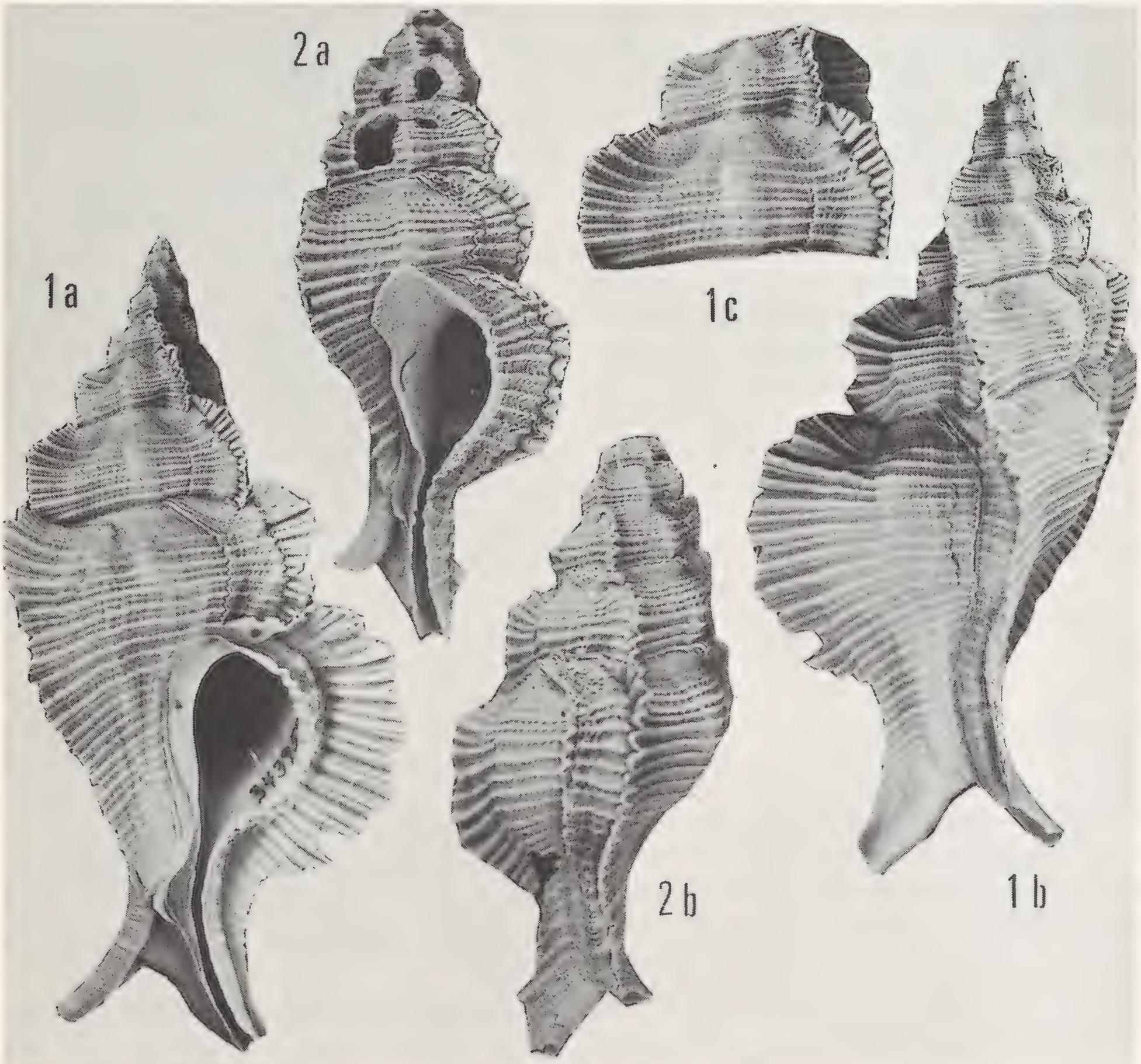

Figure 1, USNM 343958; height 63 mm, diameter 26.5 mm; Recent, Kii, Japan. Figs. 1a, 1b, X 1¼; fig. 1c, X 2 for comparison of surface ornamentation with Chipola specimen. Figure 2, USNM 646949; height 34.4 mm, diameter 16.2 mm; TU 830, Ten Mile Creek, Calhoun County, Florida; Chipola Formation, X 2.

NOTES ON THE FAUNA OF THE CHIPOLA FORMATION – VII

ON THE OCCURRENCE OF THE GENUS *CONCHOLEPAS* (GASTROPODA: THAIDIDAE), WITH THE DESCRIPTION OF A NEW SPECIES

EMILY H. VOKES
TULANE UNIVERSITY

The bizarre gastropod genus *Concholepas* Lamarck, 1801 (type species: *Concholepas peruviana* Lamarck, 1801, = *Buccinum concholepas* Bruguière, 1789) today is confined to the coast of southern Peru and Chile, where it inhabits the same ecologic niche as the abalone further north, and *Purpura patula* (Linné) in the tropics; that is to say, it clings to surf-battered rocks by means of its extremely muscular foot. The gross morphological shape of these three different gastropods also shows a marked convergence, with the aperture being greatly enlarged to accommodate the foot, and the spire being almost totally submerged. Indeed, the resemblance of *Haliotus* (the abalone) and *Concholepas* is remarkable, considering that they are only most distantly related. *Purpura patula* and *Concholepas* are more closely related, being in the same subfamily Thaidinae*, and it is an interesting exercise in evolutionary morphology to compare the shells of *Thais haemostoma, Purpura patula,* and *Concholepas concholepas.* The series of modifications from a "normal" Neogastropod to a patelloid shell are made strikingly clear within the members of this one small group. It is particularly instructive to see the small remnant of the now totally insufficient operculum still retained by *Concholepas.*

Because of this preference for a high-energy environment, fossil specimens of *Concholepas* are rare, the majority being known from late Neogene strata in Peru and Chile, where the sole Recent representatives (probably all members of a single rather variable species) still survive. (At the rate at which the local inhabitants are over-collecting this shellfish, considered a gastronomical treat by some, although not the writer, the threat of extinction is very real.) However, the genus has a respectable geologic history, being represented in the middle Miocene (Helvetian) beds of the Loire Basin of France by the rare species *Concholepas deshayesi* Rambur, 1862; in the equivalent (Balconian) beds of Australia by *C. antiquata* Tate; and in the upper Miocene of New Zealand by *C. pehuensis* (Marwick). The latter two species have been the subject of a recent review by Beu (1970), who noted that, although originally described as coming from Eocene strata, the species *C. antiquata* is actually middle Miocene in age. This error has led to the citation of "Eocene to Recent" for the genus by authors, such as Wenz (1941, p. 1122).

Other than these completely disjunct Miocene occurrences, there are no known species of *Concholepas* outside of western South America. Thus it is totally unexpected and worthy of note to find a representative of the genus in the late lower Miocene Chipola Formation of northwestern Florida, now the oldest reported occurrence of the genus. The Chipola species is much like the other Miocene forms in that the shell is markedly smoother than the Recent form (although the latter is smooth in the juvenile stages in good Haekelian fashion). The logical assumption is that the Chipola species is ancestral to both the Old World species and to the South American one. But considering the sparcity of specimens involved, and the slim chance of finding many more, the true relationships will have to remain little more than speculation.

*The family name Thaididae and the subfamily name Thaidinae have been conserved by action of the International Commission on Zoological Nomenclature (Opinion 886, 1969) in preference to the technically older, but less frequently used Purpuridae and Purpurinae.

Beu (1970, p. 45) noted that the Australasian specimens of *Concholepas* give evidence of having been deposited in deeper water than is normal for the living *Concholepas,* being on the order of 50 fathoms. They are also marked by having much thinner shells than the modern species. The Chipola specimen is also thin-shelled and this may be a factor of its early evolutionary position. The original habitat of the group may not have been as violent, and hence a thick shell would not have been critical to survival. The development of a thickened shell would have permitted the subsequent invasion of the surf-zone by the genus in later times.

It is evident that the ecologic requirements of the genus have changed somewhat through time. Today the group is confined to relatively cool water, as the Humboldt Current brings Antarctic water along the western coast of South America. The Chipola Formation was definitely tropical in its temperature, and the two specimens collected from the Chipola are found in the vicinity of a coral reef (TU 547). Perhaps the early ancestors of the line clung to coral rather than rocky shores. Certainly the expanded aperture indicates that the life-style of the genus was essentially the same, although the precise environment may have been somewhat different.

CONCHOLEPAS DREZI E. H. Vokes, n.sp.

Text figure 1

Diagnosis: Shell thin; protoconch consisting of one and one-half smooth turns; gradually becoming more ornamented to form only two post-nuclear whorls, principally the widely expanding body whorl. Spire not submerged but only slightly extended and below the level of the flaring aperture. Axial ornamentation limited to faint growth lines. Spiral ornamentation consisting of incised grooves that separate the shell into what appear to be flat-topped spiral bands of differing widths. Approximately 36 spiral grooves, which set off about 20 wider bands alternated with narrower ones; on the middle portion of the body whorl the bands regularly alternating wide and narrow, but at either extremity the pattern breaks down. Well-developed siphonal fasciole with a strong ridge curving around the anterior portion of the columellar wall as a result. Aperture oval, appressed to the body whorl at the central part, flaring posteriorly and with a flattened columellar lip at the anterior end; short open siphonal notch. Faint lirations visible on the inside of the shell, reflecting the external spiral grooves.

Dimensions of holotype: 33.5 mm, diameter 30.6 mm.

Holotype: USNM 646937.

Type locality: TU 459, east bank of Chipola River, steep bank about 1500 ft. above mouth of Taylor Lake Branch (NW ¼ Sec. 29, T1N, R9W), Calhoun County, Florida.

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimen: USNM 646937 (holotype). Other occurrence: TU locality 555.

Discussion: Concholepas drezi, n. sp., is much like the two middle Miocene species *C. deshayesi* and *C. antiquata.* It differs from *C. deshayesi* in having the spire more extended and in the greater development of the siphonal fasciole and notch. *C. deshayesi* is almost equal anteriorly and posteriorly and has no siphonal notch whatsoever. The Australian *C. antiquata* is nearer to our species but differs in having a more extended spire and a ridge at the "shoulder" that forms what is presumed to be an anal notch in the flaring aperture. In this latter trait *C. drezi* differs from both *C. antiquata* and the upper Miocene *C. pehuensis,* as both demonstrate this sinus, and it is more like the Recent *C. concholepas,* which also lacks the notch. *C. deshayesi* shows this ridge in the early stages of shell development but there is no sinus in the edge of the aperture. The nature of the spiral ornamentation is almost identical in *C. drezi, C. antiquata,* and *C. deshayesi,* differing sharply from the elaborately frilled Recent specimens. (Compare text figs. 1 and 2.) The upper Miocene *C. pehuensis* is even smoother than the early species and clearly represents a side branch that led nowhere.

It is a pleasure to name this remarkable species after Mr. Paul Drez, presently of Ft. Walton Beach, Florida (Eglin Air Force Base), who collected the type specimen. A second, incomplete, shell had previously been taken near the type locality (TU 555) but at this writing these two examples are the sole record of the genus in North America.

LOCALITY DATA

459. Chipola Fm., east bank Chipola River, steep bank about 1500 ft. above mouth of Taylor Lake Branch (NW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.

547. Chipola Fm., west bank of Chipola River, about 2000 feet above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.

555. Chipola Fm., east bank of Chipola River, about 1000 feet above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.

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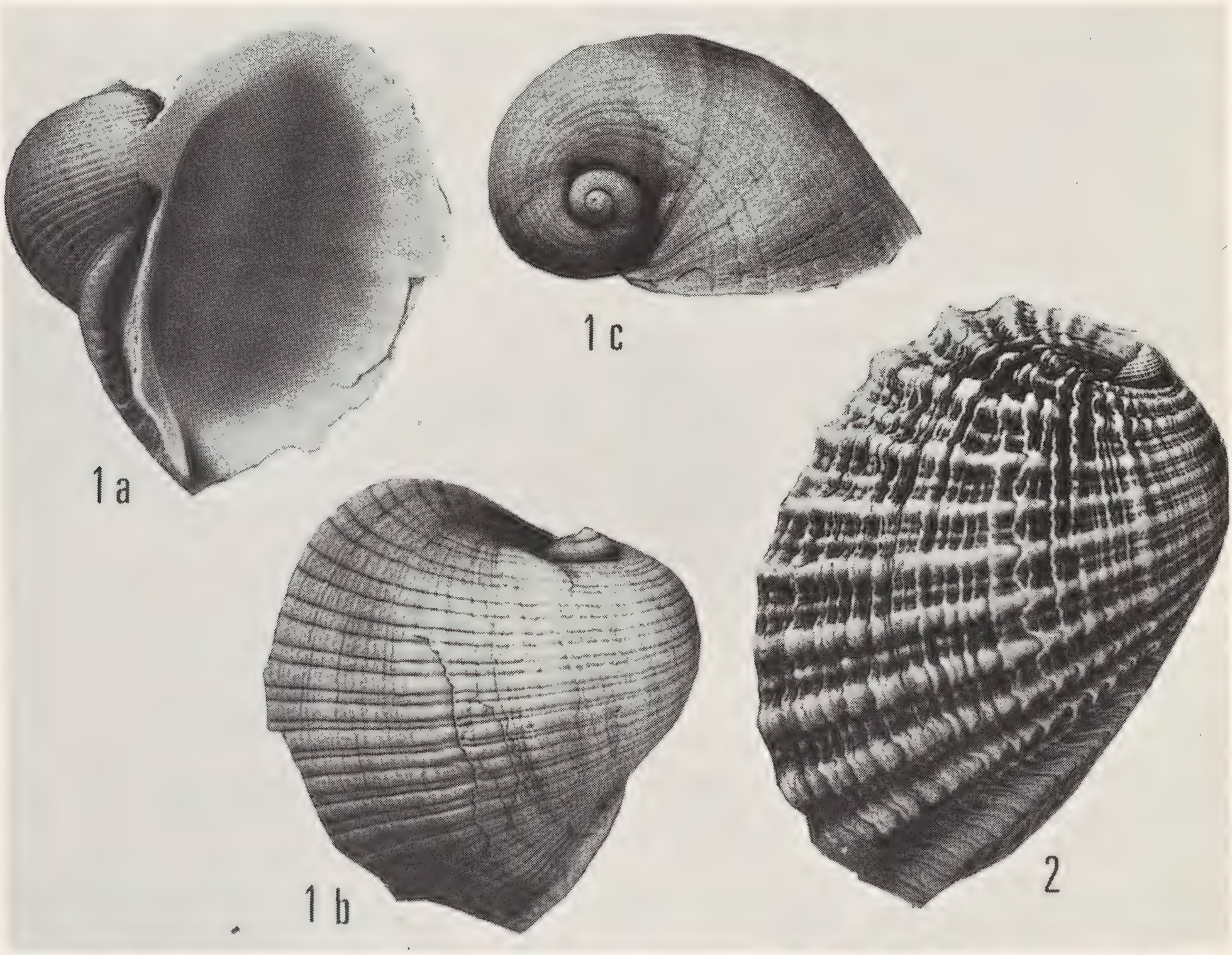

Text figure 1. *Concholepas drezi* E. H. Vokes, n. sp.; USNM 646937 (holotype); height 33.5 mm, diameter 30.6 mm; locality TU 459 (X 1½). Text figure 2. *Concholepas concholepas* (Bruguière); USNM 707684; height 47.3 mm, diameter 35.0 mm; locality TU R-226, Antofagasta, Chile, on rocks (X 1½).

NOTES ON THE FAUNA OF THE CHIPOLA FORMATION – VIII

ON THE PRESENCE OF *ARCOPAGIA (JOHNSONELLA) FAUSTA* (PULTENEY) WITH OBSERVATIONS ON THAT SPECIES

HAROLD E. VOKES
TULANE UNIVERSITY

In her important monograph on "The Molluscan Fauna of the Alum Bluff Group of Florida" Gardner (1926-1950) includes a total of 483 species from the type area of the Chipola Formation: 137 Pelecypoda, 240 Gastropoda, 6 Scaphopoda. Of these, five species of Pelecypoda, six of Gastropoda and one of Scaphopoda were identified with species present in the Recent faunas, while two other pelecypod and three gastropod species are questionably referred to Recent forms. Most of the specimens in the latter group are worn, immature or fragmentary and the author makes clear her belief that adequate material would permit their separation from the modern species to which they have been tentatively ascribed.

In view of the low percentage (2.28%) of species certainly identified with elements of the Recent fauna it is of more than usual interest to be able to record the presence in this fauna of *Arcopagia (Johnsonella) fausta* (Pulteney), a relatively common element of the faunas of southern Florida, the West Indies and the Caribbean area. Furthermore, an examination of the literature reveals only two previous records of the occurrence of the species in the fossil faunas of Florida: Dall (1900b, p. 1031) reported "a single young valve . . . found in the Pliocene marl of the Caloosahatchee" and Hoerle (1970, p. 59) listed it as rare in the Pleistocene "Glades" fauna at the Belle Glade Rock Pit, Palm Beach County. Mrs. Hoerle has informed me that this record was based upon the presence of one adult and one juvenile right valve.

Recognition of the species in the Chipola (lower Miocene) collections and consideration of its apparent rarity in the reported fossil collections prompted a search of the Florida Cenozoic materials in the Tulane University and the Hoerle collections, with the results shown in Table 1.

Some concept as to the rarity of the species may be gained by noting that it occurs in but 5 of 34 localities of "Unit A" age in the Tulane and Hoerle collections; in but 1 of 27 collections from the Caloosahatchee Formation; 3 of the 50 Pinecrest collections; and 9 of 54 collections containing over 600,000 specimens from the type area of the Chipola Formation.

Genus ARCOPAGIA (Leach MS.) Brown, 1827

Type species (by subsequent designation, Herrmannsen, 1846): *Tellina crassa* Pennant, 1776. Recent, Atlantic Coasts of Europe, south to Senegal

Subgenus JOHNSONELLA Afshar, 1969

Type species (by original designation): *Tellina fausta* Pulteney. Recent southeast Florida, the Florida Keys, Bahamas, West Indies, and north coasts of South and Central America, and islands off the east, north and west coasts of the Yucatan peninsula.

ARCOPAGIA (JOHNSONELLA) FAUSTA (Pulteney)

Plate 1, figures 1-6

Pectunculis laevibus, triquetra . . . , LISTER, 1687, Hist. syn. Method. Conchyliorum, v. 3, p. 266, fig. 102.

Tellina remies 'Linnaeus', BORN, 1780, Mus. Test Caes. Vindob., p. 36, pl. 2, fig. 11 [*non* Linnaeus, 1758, p. 676, Indo-Pacific species] ; CHEMNITZ, 1782, Neues System. Conchylien-Cabinet, v. 6, p. 121, pl. 12, fig. 112, "die westindische Sandtelline" [not fig. 113, "die ostindische Sandtelline" = *T. remies* Linné] ; Gmelin, 1791, Syst. Nat., ed. 13, p. 3239 (part).

Tellina [plate heading] BRUGUIÈRE, 1798, Encycl. Méthod., pl. 290, fig. 2 [ident. by Deshayes, 1832, Encycl. Méthod., v. 3, p. 1014, as *Tellina remies,* "elle vit dans l'Ocean americain"].

Tellina fausta PULTENEY, 1799, Cat. Dorsetshire, p. 92; DONOVAN, 1801, Nat. Hist. Brit. Shells, v. 3, pl. 98; MONTAGU, 1803, Test. Brit., v. 1, p. 64; MATON & RACKET, 1807, Trans. Linn. Soc., v. 8, p. 53, pl. 1, fig. 8; PENNANT, 1812, Brit. Zool., (new ed.), v. 4, p. 181; PULTENEY, 1813, Cat. Dorsetshire, ed. 2, p. 30, pl. 5, fig. 5; WOOD, 1815, Gen. Conch., p. 185; DILLWYN, 1817, Desc. Cat. Recent Shells, v. 1, p. 94; WOOD, 1818, Index Test., ed. 2, p. 21, sp. 74. [Considered as being a British species.]

Tellina laevis WOOD, 1815, Gen. Conch., p. 181, pl. 37, fig. 1 ["West Indies"].

Tellina (Arcopagia) fausta "Donovan." H. & A. ADAMS, 1856, Gen. Recent Moll., v. 2, p. 396; TRYON, 1869, Amer. Jour. Conch., v. 4, Appendix, p. 90; BOSS, 1966, Johnsonia, v. 4, no. 45, p. 251, pl. 134, fig. 2; pl. 135, figs. 1, 2.

Tellina elliptica SOWERBY, 1868, Conch. Icon., pt. 17, *Tellina,* pl. 43, fig. 251 [as *T. ellipsis* in index, 1869] [*non T. elliptica* Brown, 1814, *nec* Lamarck, 1818, etc.]

Tellina (Cyclotellina) fausta "Donovan." DALL, 1900, Proc. U.S. Natl. Mus., v. 23, p. 294 [November]; Dall, 1900, Wagner Free Inst. Sci., Trans., v. 3, pt. 5, p. 1031 [December].

Cyclotellina (Cyclotellina) fausta (Pulteney). THIELE, 1935, Handb. Syst. Weichtierkunde, v. 2, p. 913.

Arcopagia (Cyclotellina) fausta (Pulteney). ABBOTT, 1954, American Seashells, p. 428, pl. 40j; ABBOTT, 1958, Acad. Nat. Sci., Phila., Mon. 11, p. 135.

Arcopagia fausta (Pulteney). WARMKE & ABBOTT, 1961, Caribbean Seashells, p. 197, pl. 41,

TABLE 1

Age	Formation	T.U. Locality	Specimens
Pleistocene	"Unit-A"	201	2 right valves (H)
"	"	727	1 pair (H)
"	"	759	1 right (H) + 2 left valves (T)
"	"	768	1 pair + 1 right (H) and 1 left valve (T)
"	"	803	1 left valve (H)
Pliocene	Caloosahatchee	202	1 right valve (T)
U. Miocene	"Pinecrest Beds"	797	2 pairs (T)
"	"	933	1 right + 1 left valve (H)
"	"	1000	4 pairs + 3 right and 1 left valves (T*)
L. Miocene	Chipola	548	1 right valve (T)
"	"	550	3 right + 2 left valves (T)
"	"	554	16 right + 9 left valves (T) + 3 left valves (H)
"	"	820	1 right (T) + 1 left (H) valves
"	"	821	3 right + 2 left valves (T) + 1 right + 2 left valves (H)
"	"	825	7 right + 2 left valves (T) + 1 left valve (H)
"	"	828	1 right valve (T)
"	"	999	4 right + 1 left valves (T)
"	"	1050	3 right valves (T)

T = Tulane University Collection

H = Hoerle Collection

*Mrs. Hoerle reports (in litt.) that she has found this species to be "relatively common, generally eroded and/or broken" at this locality.

fig. 1; HOERLE, 1970, Tulane Stud. Geol. & Paleont., v. 8, no. 2, p. 59.

Arcopagia (Johnsonella) fausta (Pultney [*sic.*]). AFSHAR, 1969, Geol. Soc. Amer., Mem. 119, p. 47, pl. 15, figs. 6, 7; pl. 16, figs. 1-3.

Discussion: Although Lister (1687) had early given an excellent illustration of this species with the locality indicated as "Jamaic"; Chemnitz had figured it (1782) as "die westindische Sandtelline," a form of *"Tellina" remies* Linnaeus, "die ostindische Sandtelline"; and Gmelin (1791) had noticed, under the same specific name, that "in americanis flavedine intermista, rugis minus evidentibus," many early British authors appear to have accepted without question Pulteney's record of its occurrence in the fauna of the coast of Dorsetshire. And, as noted in the above synonymy, Wood (1815) even described the West Indian form as a separate species, *Tellina laevis*—a position that he maintained in 1818 in the *Index Testaceologicus.* Dillwyn (1817) appears to have been the first to conclude that but one species was involved, giving an extended synonymy, including the Lister illustration, and adding: "Inhabits the coasts of Jamaica. Lister. West Indies. Chemnitz. Coast of Dorsetshire. Pulteney."

Fleming (1828, p. 436) apparently believed that Pulteney's species was based upon a specimen of *Tellina crassa* Pennant, including it in his synonymy of that form. Dall (1900b, p. 1031), on the other hand, states that "this species was originally described as British from adventitious specimens . . . " but gives no supporting evidence for the statement. The type is lost (*fide* Boss, 1966, p. 251) and it is not possible to be certain just which species was represented, although the figure given by Pulteney in the second edition of his *Dorsetshire Catalogue* is somewhat more reminiscent of the West Indian than of the British shell.

There has been disagreement as to the systematic allocation of this species, apparently stemming from Dall's assignment of it to *Cyclotellina,* which he considered (1900a, p. 290) as a "section" of the "subgenus" *Arcopagia,* basing this upon the fact that the pallial sinus is partly confluent with the pallial line and is "linked by a linear scar to the anterior adductor scar" (1900a, p. 294), rather than being obliquely ascending and free from the pallial line as it is in *Arcopagia crassa* (Pennant). While not specifically so stated, it is apparent that Dall was also influenced by what appears to have been a misinterpretation of the hinge structure of the left valve of *A. crassa.* In his first statement (1900a, p. 290) Dall placed *Arcopagia* in his key under the heading: "b. Hinge with two lateral laminae in the right valve, the laminae of the left valve more or less obsolete, or absent." In his second paper (1900b, p. 1011) he specifically notes for *Arcopagia:* " . . . the posterior left lateral absent, the anterior obsolete, other teeth normal."

Specimens of *A. crassa* in the writer's collection clearly show a small left posterior

PLATE 1

ARCOPAGIA (JOHNSONNELLA) FAUSTA (Pulteney)

Figs. 1-4. Chipola Fm., lower Miocene, Florida, locality TU 554.
(1, 3) exterior and interior of left valve, USNM 646633; length 58.2 mm, height 47.8 mm, diameter 14.3 mm.
(2, 4) exterior and interior of right valve, USNM 646632; length 52.3 mm, height 43 mm, diameter 10.3 mm.

Figs. 5-6. Recent, near Michael's Rock, north side of Bonacca (Guanaja), Bay Islands, Honduras; USNM 702244.
(5) exterior of left valve, length 59 mm, height 50.1 mm, diameter 13.2 mm.
(6) exterior of right valve, length 58.9 mm, height 49.6 mm, diameter 10.2 mm; (diameter of paired valves, 22.0 mm).

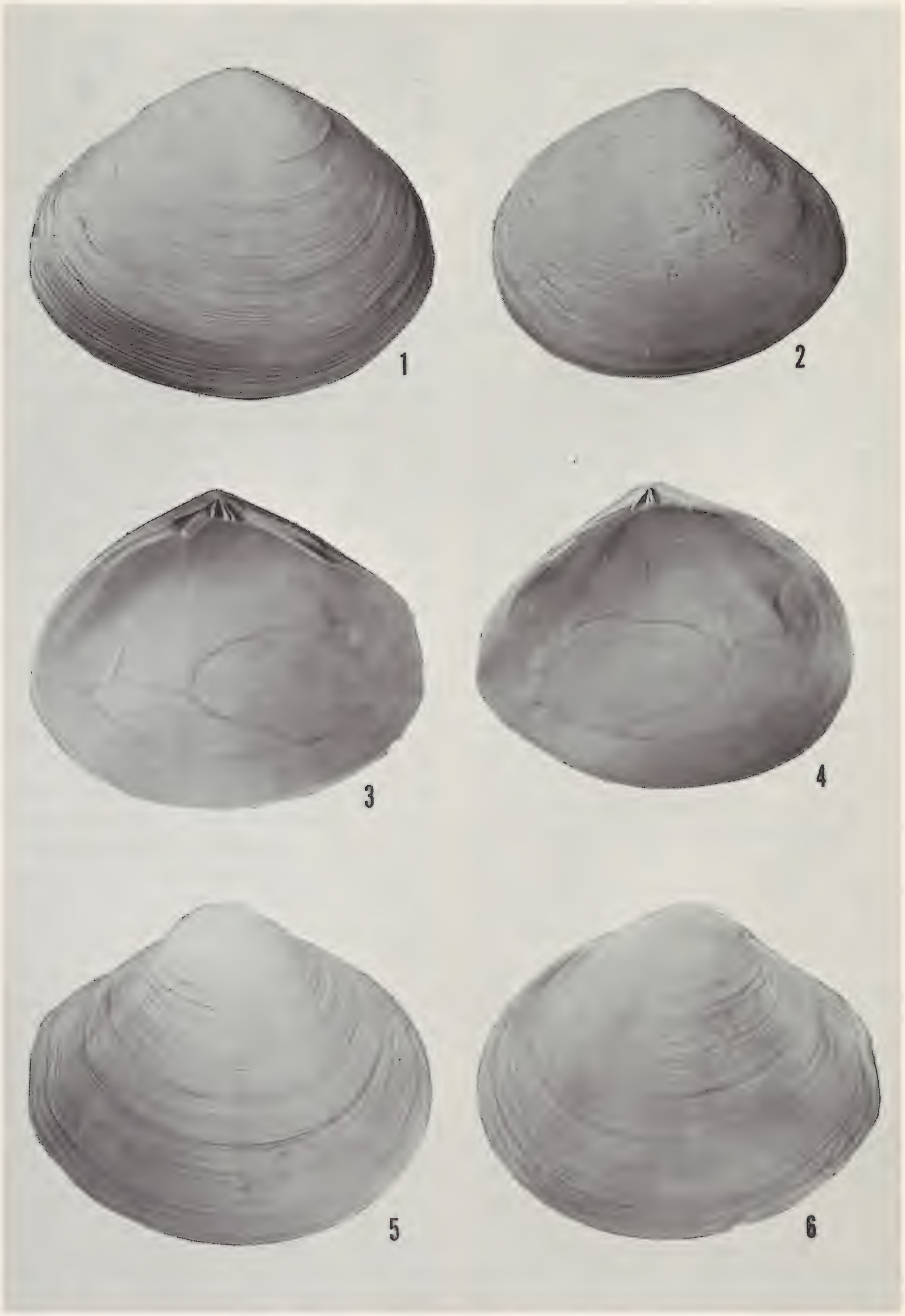

PLATE 1

lateral tooth on the valve margin immediately behind the end of the nymph plate. This tooth is identical in position with, and even a little more strongly developed than the left posterior lateral of specimens of *A. fausta* of comparable size (pl. 1, fig. 3). The left anterior lateral in *A. crassa* is also located in the same relative position as is that of *A. fausta,* and is also a little more strongly developed than is that of the latter species, being a bit more elongate and hence less triangular in profile when viewed from above. Thus, in all essential hinge features the two species are almost wholly similar.

It is also worth noting that in both species the right valve is slightly larger (one half to one millimeter longer and higher) and more inflated than the left. The difference in semi-diameter averages about three millimeters in specimens of about 60 mm length.

As observed by Dall, the principle difference between the two species lies in the nature of the pallial sinus. In *A. crassa* it is large, obliquely ascending with a rounded apex, and wholly removed from the pallial line through its entire length; in *A. fausta* the sinus is discrepant in shape in the two valves and is somewhat longer in the left valve than in the right but in both it intersects the pallial line at a point posterior to the half-length of the sinus. In the right valve the dorsal side of the sinus ascends sharply from the anterior end of the posterior adductor scar before turning, with an almost ninety degree angulation, to form a relatively straight, obliquely descending anterior dorsal margin which then rounds sharply to a similarly descending, postero-ventral trend to the pallial line. That of the left valve also rises initially, but to a lesser extent than the right sinus and then has a rather broadly rounded, rather than angulate crest leading to a less oblique postero-ventral dorsal margin that terminates in a rounded anterior extremity that is noticeably closer to the anterior adductor scar than is that of the right valve. The anterior end of both structures is connected with the anterior adductor scar by a distinct linear line (see pl. 1, figs. 3, 4). The differences in shape, which tend to become more pronounced with development of the individual, are well shown by Afshar (1969, pl. 16, figs. 2, 3).

Donax lunulata Lamarck, the type species of *Cyclotellina* Cossmann, 1886, to which Dall had referred *A. fausta,* is a relatively small form, generally less than 25 mm in length. As figured by Deshayes (1824, pl. 11, figs. 3, 4; reproduced in *Treatise on Invert. Paleontology,* Part N, Bivalvia, p. N614, fig. E 104-4a, 4b) and by Cossmann and Pissarro (1904, pl. 7, sp. 35-41) the hinge of the right valve has lateral teeth that are much more elongate and lamellar than are those of both *A. crassa* and *A. fausta,* and both anterior and posterior laterals tend to be closely parallel with the margins of the valves, rather than slightly transverse in position. The illustrations given by Afshar (1969, pl. 22, figs. 1-4) do not show the details of the hinge at all well, but they do reveal that the pallial sinus is essentially similar to that of the left valves of adult *A. fausta* but are unlike that of the right valves, not being discrepant in shape. The extent to which this may be a function of the small size of the shell is difficult to judge, especially since, as indicated above, the differences in shape are not strongly pronounced in small, immature specimens of *A. fausta* that are of the same general dimensions as the adult specimens of *Cyclotellina lunulata.*

In summary: *A. fausta,* the type species of the subgenus *Johnsonella,* has a hinge structure that agrees closely with that present in *A. crassa,* type of *Arcopagia,* but differs in all details of the pallial sinus; the latter structure, on the other hand appears to be rather similar to that present in *"Donax" lunulata,* the type species of *Cyclotellina,* but the hinges differ in the shape and position of the lateral teeth.

ECOLOGIC AND PALEOECOLOGIC CONSIDERATIONS.—According to Boss (1966, p. 253): "Robertson (1961) has noted that *Tellina fausta* at Bimini lives in a coarse sand substrate at a depth of one foot, mostly among *Thalassia* rhizomes. Abbott (1958, p. 135) reported the occurrence of this species at Grand Cayman in water 4-6 feet deep over clear sand. The maximum depth record is 15 fathoms." In his localized list of specimens examined he noted the occurrence of the species off Santa Lucia, Cuba, in 2-4 fathoms, and in Falmouth Harbor, Antigua, in 3-6 fathoms.

The writer has not been able to locate the original record of the occurrence at 15 fathoms and, in view of the apparent preference of this species for much shallower waters, is inclined to wonder whether the record may not have been based upon a shell that had been transported to the deeper environment subsequent to the death of the individual. This latter factor seems to have been significant with respect to the occurrence of the specimens from the Chipola Formation; all 63 valves collected were disassociated, with no paired valves being found.

At five of the nine localities from which these valves were collected they were associated with *Miltha chipolana* (Dall), including paired as well as disassociated valves. The recent species of *Miltha* prefer somewhat deeper waters than the Recent *Arcopagia fausta*. When the manuscript was prepared for "Observations on the Genus *Miltha* . . . " (Vokes, 1969) the only depth record for *Miltha childrenae* (Gray) of which the writer was aware was for the isolated valves dredged by the U.S. Fisheries M/V *Oregon* from 28 fathoms off Sao Luis, Est. Maranhão, Brazil. Subsequently while in Brazil he became acquainted with a paper by Kempf and Matthews (1968, p. 89) in which *M. childreni* [sic] is listed as occurring "E. Para R.; Maranhão: Ceará; R. G. Norte–21-55 meters [approximately 11-28 fathoms]." In addition, in the collections of the Museo Oceanographico de Rio Grande do Sul, there are paired valve specimens taken off Ceará in 14 fathoms and off Sao Luis, Maranhão in 17 and 28 fathoms. If one makes the unprovable assumption that the fossil forms had the same depth requirements as do the Recent representatives, this association would seem to imply that the deposits at those Chipola localities, where the association included paired valves of *Miltha,* were emplaced at a depth greater than the 6 fathoms from which living specimens of *A. fausta* have been recorded or 15 fathoms if the deepest record noted above be based upon a living specimen–possibly at depths in the 20 to 28 fathoms range. Tulane locality 554, from which 28 of the 63 valves of *A. fausta* were collected, almost three times as many as were found at any other single locality, did not yield any representation of *Miltha.* A relatively shallower water depth seems most probable.

Similar conclusions may be drawn from the association of but two isolated valves associated with several paired + disassociated valves of *Miltha carmenae* at TU locality 201 in the Pleistocene "Unit A" deposits at Belle Grade, Florida, contrasted with the presence of one paired-valve specimen of *A. fausta* and only individual valves of *M. carmenae* at TU locality 727 in the same formation.*

The basic assumption of differing depth requirements for *A. fausta* and species of *Miltha* appears to break down when applied to the upper Miocene "Pinecrest Beds" of southern Florida. Paired valves of *A. fausta* and of *M. caloosaensis* (Dall) are found in collections from both TU 797 and 1000. Both of these are spoil bank collections based upon material drag-lined from below present ground water levels and it may be that they came from different levels in the pits; if this is not the case then it might be suggested that water depths in the six to eight fathom range obtained during the time of deposition of the strata at these localities.

LOCALITY DESCRIPTIONS

The following are all Tulane University fossil localities:

"Unit A," Pleistocene:

201. Spoil banks at Belle Glade Rock Pit, just south of Belle Glade (at Belle Glade Camp), Palm Beach Co., Florida.
727. Borrow pits, 2.2 miles east of U.S. Highway 27, 15 miles south of South Bay, Palm Beach Co., Florida.
759. Spoil banks, north side of Caloosahatchee River, two miles west of Ortona Lock (NE ¼ Sec. 29, T42S, R30E), Glades Co., Florida.

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*Mrs. Emily H. Vokes informs me that the muricid species at locality 201 suggest a minimum depth in the 20-30 fathom range, (see Hoerle, 1970, p. 63, fft. 2).

768. Spoil banks, north side of Caloosahatchee River, about 5.5 miles west of Ortona Lock (NW ¼ Sec. 35, T42S, R20E), Glades Co., Florida. Material from this site includes both "Unit A" and Caloosahatchee Fmtn. faunas, mixed.
803. Spoil banks, south side of Caloosahatchee River, two miles west of Ortona Lock (NE ¼ Sec. 29, T42S, R30E), Glades Co., Florida.

Caloosahatchee Fmtn., Pliocene:

202. South bank of Caloosahatchee River, about two miles west of La Belle (SE ¼ Sec. 12, T43S, R28E), Hendry Co., Florida.

"Pinecrest Beds," upper Miocene:

797. Borrow pit material exposed during construction of "Alligator Alley," 13.3 miles east of Florida Highway 29 (T49S, R32E), Collier Co., Florida.
933. Borrow pit material exposed during construction of "Alligator Alley," 21.5 miles east of Florida Highway 29, Collier Co., Florida.
1000. Borrow pit at east end of 17th street, (T36S, R19E), about 8 miles east of U.S. Highway 30 at Sarasota, Sarasota Co., Florida.

Chipola Fmtn., late lower Miocene:

548. West bank, Chipola River, about 0.5 mile downstream from mouth of Farley Creek, (NW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
550. East bank, Chipola River, 1¼ mile below mouth of Ten-Mile Creek (NE ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
554. East bank of Chipola River immediately below power line crossing (SW ¼ Sec. 17, T1N, R9W), Calhoun Co., Florida.
820. Farley Creek, at bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
821. Farley Creek, 0.1 mile east of bridge at Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
825. Farley Creek at abandoned mill about one quarter mile west of bridge at Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
828. Farley Creek, just upstream from mouth of unnamed tributary about three-quarters of a mile west of bridge at Florida Highway 275 (SE ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
999. Farley Creek, about 900 feet downstream from bridge at Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
1050. West bank of Chipola River immediately below power line crossing, and directly across river from loc. 554 (SW ¼ Sec. 17, T1N, R9W), Calhoun Co., Florida.

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NOTES ON THE FAUNA OF THE CHIPOLA FORMATION – IX

ON THE PRESENCE OF *KUPHUS INCRASSATUS* GABB

HAROLD E. VOKES
TULANE UNIVERSITY

"Large tubes, similar to the Dominican *Kuphus incrassatus* are remarkably abundant in the Tertiary (Eocene to Miocene) limestones of the West Indies and Central America, especially in Anguilla, Puerto Rico, Haiti, Cuba, Jamaica, and Guatemala." (Woodring, 1925, p. 195).

This extensive geographical and geological distribution of *Kuphus incrassatus* has been recognized since the days when Gabb (1873, p. 246) described his species from near Guayubin, in Santo Domingo. Later Gabb (1881, p. 342) noted its occurrence in Costa Rica, as well as at other localities in Santo Domingo, adding that "it is a very common and characteristic fossil in the upper part of the Dominican Miocene." Nevertheless, there has developed a tendency to consider it as "diagnostic [in the United States] of the Chickasawhay limestone and equivalent beds" [Suwanee Limestone] of Mississippi, Alabama and Florida (see: Toulmin, 1955, p. 471; Puri and Vernon, 1964, p. 123; Copeland and Deboo, 1967, p. 45, etc.).

It is the primary purpose of the present note to record the fact that specimens of *Kuphus incrassatus* are widespread and not rare in the lime-sand facies of the stratigraphically younger Chipola Formation of western Florida, occurring in the majority of the Tulane University collections from the middle part of the section exposed along the Chipola River and from the beds of equivalent stratigraphic position and facies on Farley Creek. It is however, wholly absent from the lower and uppermost strata exposed along the Chipola River and from the entire section present on Ten Mile Creek, a tributary from the east. All of these latter areas are marked by sediments with a relatively high clay or silt content; hence there seems little basis to doubt that the distribution of *Kuphus incrassatus* was controlled by bottom sediment conditions and that it is more indicative of sedimentary facies than a guide for stratigraphic correlation.

Kuphus tubes are elongate, tapering, calcareous structures, usually of somewhat irregular or rugose surface contour. Most characteristic is the presence, in the upper smaller end of the tube, of two small tubes, one slightly larger than the other, that are encased in an extensive development of supplementary calcareous deposits (pl. 1, figs. 6-8). These smaller tubes house the inhalent and exhalent siphons of the animal, the one for the inhalent siphon being of somewhat larger diameter than that for the exhalent one. In the Recent species these tubes tend to project beyond the end of the primary tube (pl. 1, fig. 1); only very rarely is this to be observed in the fossil specimens, the tubes being brittle and tending to break away. However, fragments of these shorter tubes are commonly found in association with the larger primary ones.

These tubes agree with those formed by the Recent species *"Serpula" polythalamia* Linnaeus (1767, p. 1226), the type species of the genus *Kuphus* Guettard, 1770. It may be that the Recent species attains a larger size than did *Kuphus incrassatus,* for Dillwyn (1817, p. 1088) quotes a Mr. J. Griffiths, Esq., as follows: "The length of the longest of these shells that came into my possession was five feet four inches, and the circumference at the base nine inches, tapering upwards to two inches and a half . . . This specimen was nearly perfect, having a small part of the lower extremity entire. I have others of various dimensions, a very good one about three feet long, and four inches round, tapering to an inch and a half at the point." The largest fossil specimens known to the writer include a fragment of a tube from the type locality of the upper Miocene August Town Formation

of Jamaica in the Tulane University collections (TU 1013), which has a maximum circumference of almost five inches; the circumference of the largest Chipola specimen is four and one-half inches. Maury reported (1917, p. 399) that in the "Teredo limestone" near Caimito, Santo Domingo, the tubes "were several feet long and at first glance appeared to be exposed roots of trees." Later (1920, p. 46) she stated that they "may attain several feet in length and an inch and a quarter in diameter" [*i.e.*, a circumference of four inches].

Family TEREDINIDAE Rafinesque, 1815

Subfamily KUPHINAE Tryon, 1862

Genus KUPHUS Guettard, 1770

Type species (by subsequent designation, Cox, 1927) *Serpula polythalamia* Linnaeus, 1767. Recent, Indo-Pacific from East Africa, Madagascar and Red Sea, to East Indies and Solomon Islands, etc.

Kuphus GUETTARD, 1770, Mém. diff. Sci., v. 3, p. 139.

Furcella LAMARCK, 1801, Syst. Anim. sans Vert., p. 104.

Septaria LAMARCK, 1818, Anim. sans Vert., v. 5, p. 436 [*non* Ferussac, 1807, Gastr.]

Clossonnaria FERUSSAC, 1821, Hist. Nat. gen. et partic. Moll., Tabl. Syst., p. xlv.

Clausaria MENKE, 1828, Syn. Meth. Moll., p. 73 [n.n.].

Cuphus AGASSIZ, 1846, Nomen. Zool. Index Univ., p. 180 [err. pro *Kuphus*].

Kyphus HERRMANNSEN, 1847, Ind. Gen. Malacozool., v. 1, p. 569 [emend. pro *Kuphus*] (May, 1847).

"*Cuphus* Guettard, 1772" GRAY, 1847, Proc. Zool. Soc. London, 1847, p. 188 (November, 1847).

Cyphus FISCHER, 1887, Man. Conch., p. 1138 [emend. pro *Kuphus; non Cyphus* Schonherr, 1824, Coleopt.].

Linnaeus, in 1758, (p. 787, sp. 699) described *Serpula arenaria* with references to:

"Bonan. recr. I. t. 20, f. C.
Rumph. mus. t. 41, f. E. Solen arenarius.
Gualt. test. t. 10, f. L. N."

In 1767, in the 12th edition of the Systema Naturae, he removed the Rumphius reference from his *S. arenaria* (p. 1266, sp. 803), citing it as the sole reference to his, then newly described, *Serpula polythalamia* (p. 1266, sp. 802). Gmelin, in the 13th edition, added Rumphius' fig. D, plus Martini's "Neues Systematisches Conchylien-Cabinet" vol. 1, pl. 1, fig. 6, which is a reproduction of the Rumphius Fig. E. The Rumphius illustrations (1711, pl. 41, figs. D and E) are here reproduced for comparison with our fossil forms (pl. 1, figs. 1, 2).

PLATE 1

Figs. 1, 2. *Kuphus polythalamia* (Linnaeus), reproduction (X 0.6) of the Rumphius illustrations (1711, pl. 41, figs. D, E). (1) Rumphius' fig. E, the only illustration cited by Linnaeus when he proposed the name *Serpula polythalamia.* According to Rumphius this represents the "vero superior." (2) Rumphius' Fig. D, added to the synonymy by Gmelin, 1791, and stated by Rumphius to represent the "pars inferior" of the tube.

Figs. 3-8. *Kuphus incrassatus* Gabb. (3) USNM 646636, portion of a siphonal tube showing evidence of much damage and repair during the life of the animal (ca. X 1.6), length 64.7 mm; locality TU 826. (4) USNM 646635, tube with part of the siphonal tubes still intact (ca. X 1), length 195 mm, greatest diameter 20 mm, least diameter of main tube 14.5 mm; locality TU 825. (5) USNM 646637, another somewhat larger and irregular tube (ca. X 0.9), length 206 mm, greatest diameter 24.5 mm, least diameter 14.2 mm; locality TU 818. (6-8) Polished surfaces showing the position and size of the siphonal tubes, the larger housing the inhalent siphon. Several authors suggest that the two smaller tubes are separated by a septum; note that no such structure is present: (6) USNM 646638, an average specimen (X 2), diameter 12.7 mm; locality TU 548. (7) USNM 646634, specimen in which the inhalent siphonal tube was damaged and, as repaired, projects outside of the regular tube (X 2), greatest diameter 14.3 mm; locality TU 825. (8) USNM 646639, specimen cut at point where larger tube was bent; note that the siphonal tubes are adjacent to the inner side of the curve, and that the outer tube is much thickened on the outer side of the curve (X 2), diameter 14.7 mm; locality TU 548.

PLATE 1

The original *Serpula arenarius* is now considered to represent a tubiculous annelid while the *Serpula polythalamia* is known to be a sediment-penetrating teredid bivalve mollusk.

In addition to the variant spellings of *Kuphus* noted in the synonymy above, there have been a number of variants of the other generic names here included in the synonymy, especially of the name *Clossonnaria* Ferrusac; their inclusion in the above list would only serve to add unnecessary complication.

KUPHUS INCRASSATUS (Gabb)

Plate 1, figures 1-8

Kuphus incrassatus GABB, 1873, Amer. Philos. Soc., Trans., (N.S.), v. 15, p. 246 (near Guayubin, Santo Domingo); GABB, 1881, Acad. Nat. Sci., Phila., Jour., (Ser. 2), v. 8, p. 342, pl. 44, figs. 12a-e (first illustration, plus additional Santo Domingo localities, also reported from Sapote on Rio Reventazon, Costa Rica).

"*Teredo fistula* Lea, ? = *Kuphus incrassatus* Gabb." GUPPY, 1876, Quart. Jour. Geol. Soc. London, v. 32, p. 529 (Miocene, Haiti).

Teredo circula ALDRICH, 1886, Alabama Geol. Surv., Bull. 1, pt. 1, p. 36 (Choctaw Bluff, Ala.).

"*Teredo incrassata* Gabb (as *Kuphus*)." DALL, 1898, Wagner Free Inst. Sci., Trans., v. 3, pt. 4, p. 813 ("Oligocene of Santo Domingo, Haiti, and Costa Rica, Gabb; and of the Bowden marls, Jamaica, Henderson and Simpson. *T. fistula* Guppy (*non* H. C. Lea) from the Oligocene of Trinidad, is probably the same.")

Teredo incrassata Gabb. MAURY, 1917, Bull. Amer. Paleontology, v. 5, no. 29, p. 235, pl. 39, fig. 24 (Santo Domingo).

Teredo sp., COOKE, 1919, Carnegie Inst. Wash., Publ. 291, p. 146 ("abundant in the Oligocene of Cuba.").

Teredo incrassata (Gabb). MAURY, 1920, Sci. Survey Puerto Rico and Virgin Islands, v. 3, pt. 1 (Tertiary Mollusca), p. 45 (cites many Puerto Rican localities).

Teredo (Kuphus) incrassatus Gabb. PILSBRY, 1922, Acad. Nat. Sci., Phila., Proc., v. 73, p. 428 (Type lot is ANSP No. 2875).

Teredo (Kuphus) aff. *polythalamia* (Linné)*?* COX, 1927, Rept. Paleontology Zanzibar Protectorate, p. 62 [part, only]. (Inasmuch as fossil *tubes* [not part of the shell] cannot be distinguished from those of Recent specimens, Cox suggests using above designation for all types. The present writer prefers to continue use of Gabb's name to distinguish western Atlantic from Indo-Pacific occurrences.)

Teredo (?) incrassata (Gabb). MANSFIELD, 1937, Florida Geol. Surv., Bull. 15, pp. 49, 282, pl. 21, fig. 4 (Suwannee Ls., Florida).

"Tube large, cylindrical, irregular, surface covered by lines of growth, substance thick; apex often twisted or otherwise distorted; divided by a longitudinal septum into two tubes, often of unequal size.

"Fragments of this species are very common in the brown earthy shale east of Guayubin [Santo Domingo]. The largest I have seen is a little over an inch in diameter, and they usually occur in pieces of two or three inches in length. . . . The shelly walls are often so thickened that the internal diameter is not over half that of the outside." (Gabb, 1873)

Occurrence:

Chipola Formation: As noted above, tubes of *Kuphus incrassatus* are found at several localities from the middle portion of the formation exposed along the Chipola River, and from the strata of equivalent stratigraphic position and facies on Farley Creek, a tributary entering the Chipola River from the east side. It is represented in collections from 6 of the 22 Tulane University fossil localities in the river banks (TU 458, 459, 548, 555, 807, 950), and from 12 of the 15 localities along the course of Farley Creek (TU 818, 820, 821, 823, 824, 825, 826, 827, 828, 999, 1048).

Other United States Coastal Plain Formations: Glendon Limestone, Oligocene, Brandon, Mississippi (TU 931); Chickasawhay Marl, upper Oligocene, Alabama and Mississippi (Mansfield, 1940, p. 201, pl. 27, fig. 35); Suwannee Limestone, upper Oligocene, Florida (Mansfield, 1937, p. 282, pl. 21, fig. 4); ? Flint River Formation, Oligocene, well near Thomasville, Georgia (Mansfield, 1937, p. 50).

Central America and Antilles: (Note: references cited only for those areas not documented in the discussion or synonymy above.) Cercado and Gurabo Formations, Miocene, Santo Domingo; Miocene, Haiti; Oligocene/Miocene, Puerto Rico; Oligocene, Cuba; Oligocene/Miocene, Jamaica*: August Town Ls., upper Miocene (TU 1013), Brown's

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*Dall's record of the presence of *Kuphus* in the fauna "of the Bowden marl, Jamaica, Henderson and Simpson" is not confirmed by Woodring, (1925, p. 195) who states that the tubes of *Teredo* found in that fauna "are much smaller and thinner than tubes from the Dominican Republic to which Gabb gave the name *Kuphus incrassatus*."

Town Member of White Limestone, Oligocene (TU 1015); Anguilla Formation, lower Miocene, Anguilla; Miocene, Trinidad (Maury, 1925, p. 96, pl. 18, figs. 9, 10); upper Oligocene limestone, Rio Conchos, near Méndez, Tamaulipas, Mexico (TU 1080 and Gardner, 1945, pp. 19, 140), Meson Formation, upper Oligocene, south of Tampico, Mexico (TU 1074); lower Miocene limestone, Guatemala; Miocene, Costa Rica; Emperador Limestone, lower Miocene, Panamá (Vaughan, 1919, p. 558).

LOCALITY DESCRIPTIONS

The following are all Tulane University fossil locality numbers:

Chipola Formation, late lower Miocene:

458. East bank of Chipola River, above Farley Creek (SW ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
459. East bank of Chipola River at steep bank about 1500 feet above mouth of Taylor Lake Branch (NW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
548. West bank of Chipola River (NW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
555. East bank of Chipola River, about ¼ mile below mouth of Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
807. West bank of Chipola River, at north edge Sec. 20, T1N, R9W, Calhoun Co., Florida.
818. Farley Creek, south bank, 0.1 mile west of bridge on Florida highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
820. Farley Creek, north bank, at bridge of Florida highway 275, (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
821. Farley Creek, north bank, 0.1 mile east of bridge of Florida highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
823. Farley Creek, south (east) bank, about 2000 feet east of bridge of Florida highway 275 (SE ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
824. Farley Creek, south (east) bank about 0.5 mile east of bridge of Florida highway 275 (SE ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
825. Farley Creek, north bank at abandoned mill about ¼ mile west of bridge of Florida highway 275 (SW ½ Sec. 21, T1N, R9W), Calhoun Co., Florida.
826. Farley Creek, north bank, about 400 feet downstream from loc. 825 (on line between Secs. 20 and 21, T1N, R9W), Calhoun Co., Florida.
827. Farley Creek, north bank about 0.5 mile west of bridge on Florida highway 275 (SE ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
828. Farley Creek, north bank, immediately upstream from mouth of unnamed tributary and 3/4 mile below bridge on Florida Highway 275 (SE ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
950. Chipola River, west bank, about 2000 feet above mouth of Farley Creek (near north edge of SW ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
999. Farley Creek, south bank, about 1000 feet west of bridge on Florida highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
1048. Farley Creek, southeast bank, about 0.8 mile east of bridge on Florida highway 275 (NE ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.

Non-Chipola localities cited:

931. Glendon Ls., Oligocene, quarry of Marquette Cement Co., south of U.S. highway 80 at Brandon, Mississippi.
1013. August Town Fm., upper Miocene, Hope River Gorge at August Town, Parish of St. Andrew, near Kingston, Jamaica.
1015. Brown's Town Fm., Oligocene, at Orange Park, east of Claremont, Parish of St. Ann, Jamaica.
1074. Meson Fm., upper Oligocene, State of Vera Cruz, road cut on Mexico highway 180, 8.4 miles south of ferry landing on Rio Panuco opposite Tampico, Tamps.
1080. Upper Oligocene coralliferous limestone, top of first hill west of Méndez, Tamaulipas, Mexico, on Méndez-China road.

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REVIEW

PRINCIPLES OF GEOLOGY, by Charles Lyell; with an introduction by Martin J. S. Rudwick: reprinted in facsimile. Distributed by Stechert-Hafner Service Agency, Inc., New York, 1970, 3 vols.; I, xxv, front., xv + 511 pp. with 2 pls. and 33 woodcuts; II, iv, front., xii + 330 pp. with folding map and 9 woodcuts; III, iv, 4 pls. shells, map, front., xxxii + 398 pp. with 93 woodcuts, + 109 pp. comprising two appendices, a glossary and index; $71.50

Sir Charles's *Principles of Geology*, the most influential book in the history of this branch of science, is here reprinted in the original state of the first edition for the first time. These three volumes appeared separately in 1830, 1832, and 1833 and second editions of volumes I and II were published in 1832 and 1833 before the third volume first appeared. Thus, sets of first editions are relatively rare and previous to this reprint edition generally inaccessible. Most libraries contain mixed sets of the first two editions or later versions. During Lyell's lifetime the *Principles* was constantly in revision and eleven subsequent editions appeared between 1834 and 1875, representing a remarkable degree of success and influence on geologic thought. As Doctor Rudwick states in his lengthy analytical introduction, though the *Principles* "should be numbered among the most revolutionary books in the history of science . . . it has suffered in modern times from being more venerated than read." He attributes this condition not only to the inaccessibility of the first edition but to its great length of more than 1200 pages. Lyell's original conception of the scope and nature of geology can be gained only from study of the first edition before the extensive modifications appeared in response to its success and the continuous discussion and criticism it evoked within the scientific community. Doctor Rudwick also calls attention to the approach of Lyell as revealed by the subtitle, "grounded on the methodological principle of actualism, the *attempt* to interpret and explain the past in terms of 'actual causes,' i.e., processes observable in the present." This handsome and well-done reprint will permit modern historians of geology and all other interested readers to re-evaluate Lyell and his work in the original version.

H.C.S.

NOTES ON THE FAUNA OF THE CHIPOLA FORMATION – X
ON THE OCCURRENCE OF THE VOLUTID SUBGENUS *ENAETA*

JEAN M. CATE
*SANIBEL, FLORIDA**

During the course of recent work on the Chipola Mitridae, I came across a group of shells in the Tulane University Geology Department collection that seemed out of place in this family. Upon further study, I determined that the species had first been described by Maury as a *Caricella* (Family Volutidae). Dall later described the same species as a *Strigatella* (Family Mitridae), and Gardner, although correctly synonymizing the Dall species with that of Maury, failed to note the discrepancies between the shell's characters and the characters of the named genus, thus erroneously retaining the species in the mitrid genus *Strigatella.*

The type species of *Strigatella* is the Indo-Pacific (Recent) *Strigatella paupercula* (Linné, 1758); a typical specimen is illustrated at Plate 1, figure 6. Modern workers (Cernohorsky , 1970; Coan, *et al.*, in press.) treat *Strigatella* as a subgenus of *Mitra,* no longer as a distinct genus.

There are several important characteristics in the species *isabellae* which would seem to preclude its placement in *Strigatella;* first of these is the presence of axial ribbing. The species in *Strigatella* are either smooth or spirally grooved, but never longitudinally ribbed; axial ribbing is present, however, in the volutid genus *Lyria* Gray, 1847. Secondly, the arrangement of the columellar folds is not consistent with *Strigatella;* columellar folds are typically stronger anteriorly in the volutids, but posteriorly in the mitrids; *isabellae* has definitely volutid columellar plaits, as the anterior folds are visibly stronger than the posterior ones. Furthermore, the plaits are more or less transverse, another typical character of the genus *Lyria,* the columellar folds being typically oblique in the Mitridae. Finally, the presence of a blunt tooth on the labrum is an important characteristic of *Lyria* subgenus *Enaeta* Adams & Adams, 1853; in fact, it is the single character by which this subgenus is differentiated. Also, while the labrum is thickened in both *Lyria* and *Strigatella,* there is a difference in the manner in which it is thickened in the two genera; in *Lyria* s.s. the lip is simply heavy but smooth, whereas in *Strigatella* there is a large callus area present, and frequently a notch as well—but never a tooth. The blunt tooth, or nodule, so prominent in this species is typical only of species of *Enaeta.* The type species of *Enaeta* is the Panamic (Recent) *Lyria (Enaeta) harpa* (Barnes, 1824) = *L. (E.) barnesii* (Gray, 1825); typical specimens are illustrated on Plate 1, figures 4, 5.

The subgenus *Enaeta* shares certain morphological characteristics with another taxon, the closely related volutid genus *Mitreola* Swainson, 1833, type: *Mitreola monodonta* (Lamarck, 1803), from the Paris Basin, France. One of the most conspicuous differences between *Mitreola* and *Enaeta* is the nature of the color pattern. Although *Mitreola* is known only from the Eocene, fossil specimens from the Paris Basin display, under ultraviolet light, a color pattern similar to that seen in the modern *Strigatella,* while the Chipola specimens of *Enaeta isabellae* show a pattern almost identical with that of the Recent *Enaeta barnesii.* (Compare Plate 1, figs. 3 and 5, with figs. 6a and 7b.) Moreover, in *Mitreola* the callosity on the outer lip is a simple thickening and bears no resemblance to the labral nodule present in *Enaeta;* there is also a prominent parietal wall, which is lacking in *Enaeta;* the shell in *Mitreola* is more slender, and most importantly, the nucleus in *Mitreola* is more prominent and more mammillate. Pilsbry and Olsson (1954) removed the genus *Mitreola*

*Research Assistant in Invertebrate Zoology, Los Angeles County Museum of Natural History, Los Angeles, California 90007.

from its former placement in Mitridae, placing it in the Volutidae, subfamily Lyriinae. It seems evident that additional work should be done in the relationships among these closely allied forms.

The differences among the various taxa discussed herein, and the need for re-assigning Maury's species to a different family, genus and subgenus, will be readily seen by a comparison of the figures on Plate 1. For all the reasons given, I am here assigning *Caricella isabellae* Maury, 1910, to a more appropriate place in the Volutidae as *Lyria (Enaeta) isabellae* (Maury, 1910).

The presence of the subgenus *Enaeta* in the Chipola Formation is of more than usual interest, for according to Woodring (1964, p. 289) the only other known fossil species of *Enaeta* occur in younger Miocene deposits of Panamá and the Dominican Republic, making

PLATE 1

Figures

1-3. *Lyria (Enaeta) isabellae* (Maury, 1910) (X 2)

1. Holotype – *Caricella isabellae* Maury, 1910.
   PRI 3446; height 27.4 mm, width 14.0 mm, length of aperture 19.0 mm.
   Locality: "Bailey's Ferry, Florida." Chipola Formation, late lower Miocene.
2. Holotype – *Strigatella americana* Dall, 1915.
   USNM 114343; height 28.2 mm, width 14.0 mm, length of aperture 19.0 mm.
   Locality: USGS 2212 (= TU 457). Chipola Formation, late lower Miocene.
3. Color pattern as revealed by ultraviolet light.*
   USNM 646935; height 24.2 mm, width 13.0 mm., length of aperture 17.4 mm.
   Locality: TU 951. Chipola Formation, late lower Miocene.

4-5. *Lyria (Enaeta) barnesii* (Gray, 1825) (X 2) [Type of *Enaeta* Adams & Adams, 1853]

4. Cate coll. no. 59-2230; height 31.9 mm, width 16.1 mm, length of aperture 22.6 mm. (Shell whitened to show ornamentation.)
   Locality: Tenacatita Bay, Jalisco, Mexico, 20-40 fms; leg. G. Willett. Recent.
5. USNM 707683; height 31.3 mm, width 17.5 mm, length of aperture 22.4 mm.
   Locality: TU R-166, Barra de Navidad, Jalisco, Mexico. Recent.

6. *Strigatella paupercula* (Linné, 1758) (X 2) [Type species of *Strigatella* Swainson, 1840]
   Cate coll. no. 68-4539; height 27.5 mm, width 12.0 mm, length of aperture 15.2 mm.
   Locality: Coron, Philippine Islands. Recent.
   (Fig. 6a, color pattern; fig. 6b, whitened to show ornamentation.)

7. *Mitreola monodonta* (Lamarck, 1803) (X 2½) [Type species of *Mitreola* Swainson, 1833]
   USNM 646936; height 20.0 mm, width 9.4 mm, length of aperture 8.0 mm.
   Locality: Grignon, France. Middle Eocene.
   (Fig. 7a, white light; fig. 7b, color pattern as revealed by ultraviolet light.*)

*The photographs taken with ultraviolet light are actually double negatives, reproducing the original color pattern present on the shell. The ultraviolet light gives a negative image unless thus converted. For further discussion of the technique involved see Vokes and Vokes, 1968, Tulane Stud. Geol., v. 6, no. 2, p. 76. The specimen of *Mitreola* had a brilliant fluorescence even without treatment in bleach, suggesting that the original color pattern was very intense in life, much like *Strigatella*.

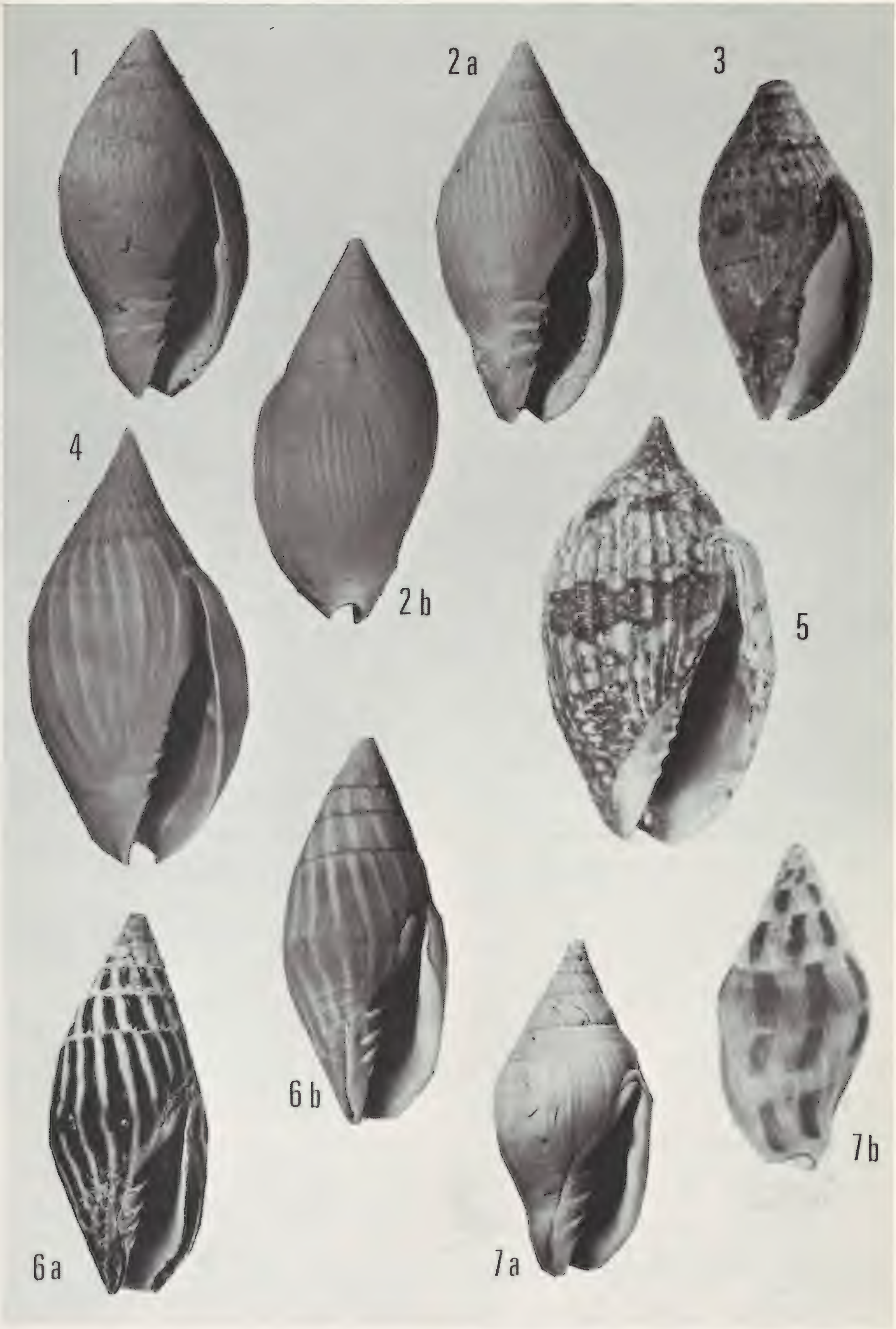

PLATE 1

this the oldest known fossil occurrence of the group. Pilsbry and Olsson (1954, p. 24) anticipated me in observing that *"Strigilla" [sic] americana* Dall is an *Enaeta,* but in the hopes of focusing attention upon its identity and significance this more detailed note is presented.

LYRIA (ENAETA) ISABELLAE
(Maury, 1910)

Plate 1, figs. 1-3

Caricella isabellae MAURY, 1910, Bulls. Amer. Paleontology, v. 4, no. 21, p. 17, pl. 4, fig. 7. (See Plate 1, fig. 1)

Strigatella americana DALL, 1915, U.S. Natl. Mus., Bull. 90, p. 61, pl. 9, fig. 2. (See Plate 1, figs. 2a, 2b)

Strigatella isabellae (Maury). GARDNER, 1937, U.S. Geol. Surv. Prof. Paper 142-F, p. 419.

Enaeta americana (Dall). PILSBRY and OLSSON, 1954, Bulls. Amer. Paleontology, v. 35, no. 152, p. 24, pl. 3, fig. 3 (holotype).

[Enaeta] isabellae Maury. WOODRING, 1964, U.S. Geol. Surv. Prof. Paper 306-C, p. 289 (with *"Strigatella" americana* Dall in synonymy).

Mitreola americana (Dall). CERNOHORSKY, 1970, Auckland Inst. Mus., Bull., No. 8, p. 88, pl. 12, fig. 5 (after Olsson and Pilsbry, 1954, pl. 3, fig. 3).

"The protoconch is very small, obtuse, smooth, and highly polished and performs between two and two and one-half revolutions. The initial turn is broadly rounded posteriorly and almost entirely immersed. The succeeding one and one-half turns are feebly convex, flattening laterally toward the close of the protoconch. The dividing line between the conch and protoconch is indicated by a slight change in the texture of the shell, the increased lateral flattening of the whorl, and the introduction of faint spiral and incremental striae. The spirals are low and obscure, finely waved, and more or less irregular. They usually run from 9 to 13 to the whorl. The axial sculpture is incremental in character and irregular in development. Both the axial and the spiral sculpture have been somewhat exaggerated in Dall's figure. Miss Maury's type was doubtless slightly weathered, and the ornamentation is so obscure that it is easily obliterated by only a slight degree of erosion. The suture line is deeply impressed and is dragged backward near the aperture. The aperture is obliquely lenticular in outline and acutely angulated posteriorly. The anterior of the four labial plications is less elevated and less produced than any of those behind it. The siphonal notch is deep but not conspicuously wide; its margins are parallel and obliquely directed." (Gardner, 1937)

Figured specimens: Fig. 1, PRI 3446 (holotype-*Caricella isabellae* Maury); height 27.4 mm; width 14.0 mm; exact locality unknown. Fig. 2, USNM 114343 (holotype-*Strigatella americana* Dall); height 28.2 mm; width 14.0 mm; locality USGS 2212 = TU 457. Fig. 3, USNM 646935; height 24.2 mm; width 13.0 mm; locality TU 951. Other occurrences: TU locality nos. 458, 546, 830, 998.

Discussion: The type locality of Maury's specimen is not known, as she cited only "Chipola marls, Bailey's Ferry, Fla." As has been noted previously in this series, the Chipola Formation does not occur at Bailey's Ferry and thus her specimen was probably from somewhere farther downstream. The type locality for Dall's species is USGS 2212 (= TU 457) and it is this which must be employed as the type locality for *"Caricella" isabellae* Maury. In the Tulane Geological Collections the species has not been collected at TU 457, and it is rare throughout the entire Chipola Formation with only 42 specimens known at the present time from all localities. The majority of these specimens were found in the lower beds along Ten Mile Creek but this is probably facies limited and not time limited, as a few specimens have also been taken at stratigraphically higher localities.

ACKNOWLEDGMENT

My thanks go to Dr. Emily H. Vokes, who first brought this interesting problem to my attention and offered helpful guidance in the further preparation of this paper. She has also kindly provided the illustrations.

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PILSBRY, H. A., and A. A. OLSSON, 1954, Systems of the Volutidae: Bulls. Amer. Paleontology, v. 35, no. 152, p. 271-306, pls. 25-28.

WOODRING, W. P., 1964, Geology and Paleontology of Canal Zone and Adjoining Parts of Panama; Part 3, Description of Tertiary Mollusks (Gastropods: Columbellidae to Volutidae): U.S. Geol. Surv. Prof. Paper 306-C, p. 240-297, pls. 39-47, 1 table.

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NOTES ON THE FAUNA OF THE CHIPOLA FORMATION – XI
HELIUM–URANIUM DATING STUDIES OF CORALS

MICHAEL L. BENDER
GRADUATE SCHOOL OF OCEANOGRAPHY
UNIVERSITY OF RHODE ISLAND
NARRAGANSETT, RHODE ISLAND

Fanale and Schaeffer (1965) first recognized that the helium–uranium method might be a way to reliably date fossil corals. The method is based on the fact that when uranium and its radioactive daughters decay, they produce helium atoms at a known rate. From measured helium and uranium concentrations one can calculate an "age." This "age" will be reliable provided that diagenetic processes have not leached or contaminated the fossil and that the gaseous helium has not leaked out.

Fanale and Schaeffer (1965) and later Bender (1970, 1972) extensively tested the reliability of the method by determining He/U ages on a total of about fifty fossil corals from five different localities. Only in the case of samples from Eniwetok drill holes were ages of various samples internally inconsistent (nonconcordance between radiometric and relative stratigraphic ages). These anomalous results were traced to diagenetic addition of uranium or one of its daughters. Analyses of samples from other areas showed that this addition was absent or very slight elsewhere.

Samples from the Caloosahatchee and Pinecrest formations were analyzed and gave results that were internally consistent and in agreement with the loosely constrained stratigraphic ages–1.8 to 2.5 myr for the Caloosahatchee and 3.7 myr for the Pinecrest (see Bender 1970, 1972 for results and discussion). Samples from the upper Pleistocene of Barbados gave ages in agreement with those determined by another radiometric method, after a small empirical correction for "inherited helium" (that present in living corals) was made.

Nine corals from the Chipola formation were dated by the helium–uranium method. The ages are shown in Table I. The average

Table I. Helium – uranium dates of Chipola corals.

Tulane Locality Number	He/U Age (million years)
655 A	15.8
821 A	16.2
821 B	16.2
821 C	17.8
458 A	16.5
458 B	15.6
546 A	17.2
547 A	14.1
547 B	15.6

Locality numbers are arranged in stratigraphic sequence (youngest at top), as nearly as can be determined.

age is 16.1 million years (myr); the uncertainty is comparable to the standard deviation of $\pm$1 myr.

The ages of the different samples agree well with one another, and this is evidence that the results are reliable. However, it does not completely rule out the possibility that some process has raised or lowered all ages by about the same amount. For example, if all corals had lost half of their uranium continuously during diagenesis, radiometric ages would be uniformly higher than the true ages by about one-third. Such an error is unlikely but not impossible.

The helium–uranium age is in good agreement with the absolute age estimated from the planktonic foraminiferal assemblage studied by Akers (1972) and correlated with standard zonations. This agreement of two lines of evidence lets us place more confidence in the result.

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AKERS, W. H., 1972, Planktonic foraminifera and biostratigraphy of some Neogene formations, northern Florida and Atlantic Coastal Plain: Tulane Stud. Geol. Paleont., v. 8, p. 1-139, pls. 1-60, 4 figures, 1 map.

BENDER, M. L., 1970, Helium–uranium dating of corals: Columbia U., Ph.D. Thesis, 149 p.

BENDER, M. L., 1972, Helium–uranium dating of corals: Geochim. et Cosmochim. Acta, in press.

FANALE, F. P., and SCHAEFFER, O. A., 1965, Helium–uranium ratios for Pleistocene and Tertiary fossil aragonites: Science, v. 149, p. 312-317.

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REVIEW

PAST AND PRESENT CAUSES IN GEOLOGY, by Lucien Cayeux. Translated (from French) and edited by Albert V. Carozzi. xxiv + 161 pp. (1941), reprint (1971) by Hafner Publ. Co., New York, $13.95

THE NOMENCLATURE OF PETROLOGY, by Arthur Holmes. v + 284 pp. (1920, 1928), reprint (1971) by Hafner Publ. Co., New York, $9.95

This publishing company is continuing a most valuable service to the geological fraternity, *i.e.*, bringing back into print some of the "mid-period" classics of our science. And, as in the case of the Cayeux volume, by presenting them in the English language with copious comments and expanded footnotes by the translator and editor, this edition is certainly far more useful to us than was the original. The Holmes work is a facsimile of the 1920 edition but, having been long out-of-print and really quite scarce (and thus expensive, when found), this edition is also very welcome.

Little needs to be said concerning books which have been well known to scholars for the many decades represented by these two. Holmes' book, being a thorough glossary of the petrographic terms used in English publications in that era, plus language dictionaries for many French and German petrographic terms, also Latin and Greek words and prefixes used in constructing the nomenclature, obviously leads to a better understanding of the AGI Glossary in common use today. The Cayeux book has been a controversial one, with some authorities saying that it refutes the principal of uniformity; the editor says that, in his opinion, it does not. A generation of new readers will now have the opportunity to determine this for themselves.

Hamilton M. Johnson
Dept. of Geology
Tulane University

November 28, 1972

NOTES ON THE FAUNA OF THE CHIPOLA FORMATION – XII
SUPPLEMENTARY BIBLIOGRAPHY

ROBERT C. HOERLE
WEST PALM BEACH, FLORIDA

Julia Gardner's *Molluscan Fauna of the Alum Bluff Group of Florida* (U. S. Geol. Surv. Prof. Paper 142, 1926-1950) is the most important source of paleontological information pertaining to the Chipola Formation; however, since Gardner's time other studies of significant value have become available to students of this fauna. Because a portion of this information is contained in articles apparently unrelated to the Chipola Formation an obvious requirement for an up-dated bibliography exists.

Continued efforts by workers have resulted in the recovery of many new species unknown in the limited material available to Gardner. In addition to new species, there are also those that Gardner believed to be restricted to the Shoal River or Oak Grove formations but which are now known to occur in the fauna of the Chipola Formation. Of the numerous species known to be present in more than one member of the group, to date only *Chicoreus (Siratus) gilli* (Maury), *Chicoreus (Siratus) nicholsi* (Gardner) and *Turbinella dodonaia* (Gardner) have been reviewed. Hopefully this number will be increased in the future. The reader should refer to accompanying papers in this volume for additional data on the Chipola fauna.

The following are works that have come to the attention of the writer; however no exhaustive search of the literature has been conducted. Needless to say, changes in generic assignment are to be considered only as the opinion of their author and not necessarily definitive.

The papers listed below are solely those that make a significant contribution to the knowledge of the fauna. Citations that contain only comparisons of Chipola species with those in other faunas have not been included.

PHYLUM *MOLLUSCA*

ABBOTT, R. T., 1968, Indo-Pacific Moll., v. 2, no. 9, Cassidae.

Cassis delta Parker, p. 51, pl. 24, figs. 1, 2 (after Parker).
Phalium granulatum aldrichi Dall, p. 163, pl. 150 (after Dall). (Originally *Phalium aldrichi* Dall.)

CERNOHORSKY, W. O., 1970, Auckland Inst. and Mus., Bull., No. 8.

Mitreola americana (Dall), p. 88, pl. 12, fig. 5; figure only, no discussion. (Originally *Strigatella americana* Dall.)

GARDNER, JULIA, 1936, Florida Geol. Surv., Bull. 14.

Astarte (Ashtarotha) sp., p. 20, pl. 4, fig. 1. (First record of occurrence in the Chipola Formation.)
Chione (Chione) oulotricha Gardner, n. sp., p. 33, pl. 7, figs. 1-2.

GERTMAN, R. L., 1969, Tulane Stud. Geol. Paleont., v. 7, no. 4.

Typhis (Rugotyphis) keenae Gertman, n. sp., p. 151, pl. 2, figs. 2a,b,c; 3a,b.
Typhis (Typhinellus) chipolanus Gertman, n. sp., p. 155, pl. 1, figs. 4a,b.
Typhis (Talityphis) obesus Gabb, p. 160, pl. 4, figs. 1-4.
Siphonochelus (Laevityphis) linguiferus (Dall), p. 174, pl. 6, figs. 5a,b.
(Originally *Typhis linguiferus* Dall.)
Pterotyphis (Pterotyphis) calhounensis Gertman, n. sp., p. 182, pl. 8, figs. 1a,b.
Pterotyphis (Tripterotyphis) vokesae Gertman, n. sp., p. 184, pl. 8, figs. 3a,b.

[The following papers by Glibert, and Glibert and Van de Poel, while primarily a listing of the foreign Cenozoic fossils in the collections of the Brussels Museum, contain a considerable amount of systematic

discussion and consequent revision of generic assignments.]

GLIBERT, MAXIME, 1960, Mém. Inst. Royal des Sci. Nat. de Belgique, ser. 2, fasc. 61.

Prunum (Leptogouana) bellum (Conrad, 1868), p. 87. (Chipola record either an error in locality data or misidentification of *Marginella (Volvarina) oryzoides* Gardner.)

GLIBERT, MAXIME, 1962, Mém. Inst. Royal des Sci. Nat. de Belgique, ser. 2, fasc. 68.

Neritina (Vitta) chipolana Dall, 1892, p. 108. (As *Smaragdia chipolana* in Gardner.)

GLIBERT, MAXIME, 1962, Mém. Inst. Royal des Sci. Nat. de Belgique, ser. 2, fasc. 69.

Turritella subgrundifera Dall, 1892, p. 99.
Turritella (Torcula) chipolana Dall, 1892, p. 103. (Originally *Turritella chipolana* Dall.)
Obtortio (Alabina) boiplex (Dall, 1892), p. 189. (Originally *Bittium (styliferina) boiplex* Dall.)
Tenuicerithium chipolanum (Dall, 1892), p. 197. (Originally *Bittium chipolanum* Dall.)
Tenuicerithium permutabile (Dall, 1892), p. 198. (Originally *Bittium permutabile* Dall.)
Hemicerithium cossmanni (Dall, 1892), p. 212. (Originally *Bittium cossmanni* Dall.)

GLIBERT, MAXIME, 1962, Mém. Inst. Royal des Sci. Nat. de Belgique, ser. 2, fasc. 70.

Acteocina incisa kolos Gardner, p. 40.

GLIBERT, MAXIME, 1963, Mém. Inst. Royal des Sci. Nat. de Belgique, ser. 2, fasc. 73.

Calyptraea (Crucibulum) chipolana Dall, 1892, p. 18. (Originally *Crucibulum auriculum* var. *chipolanum* Dall.)
Crepidula (Janacus) plana (Say, 1822), p. 22. (Originally *Crepidula plana* Say.)
Strombus aldrichi Dall, 1890, p. 42.
Neverita (Glossaulax) chipolana (Dall, 1892), p. 84. (Originally *Polynices (Neverita) chipolana* Dall.)
Tectonatica floridana (Dall, 1892), p. 103. (Probably = *"Natica (Tectonatica ?)" platabasis* Gardner named for the Chipola specimens of "*floridana* Dall" the type specimen of which is from the Tampa Ls. at Ballast Point, near Tampa, Fla.)

GLIBERT, MAXIME, and VAN DE POEL, LUC, 1965, Mém. Inst. Royal des Sci. Nat. de Belgique, ser. 2, fasc. 77.

Nuculana (Saccella) proteracuta (Gardner, 1926), p. 22. (Originally *Leda proteracuta* Gardner.)
Anadara (Cunearca) initiator (Dall, 1898), p. 58. (Originally *Scapharca (Cunearca) initiator* Dall.)
Anadara (Cunearca) santarosana geraetera (Gardner, 1926), p. 58. (Originally *Diluvarca (Diluvarca) santarosana geraetera* Gardner.)

GLIBERT, MAXIME, and VAN DE POEL, LUC, 1965, Mém. Inst. Royal des Sci. Nat. de Belgique, ser. 2, fasc. 78.

Lyropecten (Nodipecten) condylomatus (Dall, 1898), p. 25. (Originally *Pecten (Nodipecten) condylomatus* Dall.)
Mimachlamys chipolana (Dall, 1898), p. 31. (Originally *Pecten (Aequipecten) chipolanus* Dall.)
Plicatula densata Conrad, 1843, p. 44.
Pycnodonte (Alectrionella) haitensis (Sowerby, 1850), p. 69. (Originally *Ostrea haitensis* Sowerby.)

GLIBERT, MAXIME, and VAN DE POEL, LUC, 1966, Mém. Inst. Royal des Sci. Nat. de Belgique, ser. 2, fasc. 81.

Caryocorbula (Bothrocorbula) synarmostes (Dall, 1898), p. 54. (Originally *Corbula (Bothrocorbula) synarmostes* Dall.)

GLIBERT, MAXIME, and VAN DE POEL, LUC, 1966, Mém. Inst. Royal des Sci. Nat. de Belgique, ser. 2, fasc. 82.

Chione (s.s.) *chipolana* Dall, 1903, p. 43.
Chione (Lirophora) burnsii (Dall, 1900), p. 44. (Originally *Venus (Anaitis) burnsii* Dall.)

GLIBERT, MAXIME, and VAN DE POEL, LUC, 1967, Mém. Inst. Royal des Sci. Nat. de Belgique, ser. 2, fasc. 83.

Lucina (s.s.) *glenni* (Dall, 1903), p. 16. (Originally *Phacoides (Here) glenni* Dall.)
Lucina (Pleurolucina) erosa (Dall, 1903), p. 20. (Originally *Codakia (Jagonia) erosa* Dall.)
Phacoides (Lucinisca) chipolanus (Dall, 1903), p. 20. (Originally *Codakia (Jagonia) chipolana* Dall.)
Anodontia (Pegophysema) janus (Dall, 1903), p. 42. (Originally *Lucina janus* Dall.)
Anodontia (Pegophysema) santarosana (Dall, 1903), p. 42. (Originally *Lucina santarosana* Dall.)

GLIBERT, MAXIME, and VAN DE POEL, LUC, 1970, Mém. Inst. Royal des Sci. Nat. de Belgique, ser. 2, fasc. 84.

Cerastoderma (s.s.) *chipolanum* (Dall, 1900), p. 40. (Originally *Cardium (Cerastoderma) chipolanum* Dall.)
Trigoniocardia (s.s.) *simrothi* (Dall, 1900), p. 59. (Originally *Cardium (Trigoniocardia) simrothi* Dall.)
Trigoniocardia (Americardia ?) burnsi (Dall, 1900), p. 60. (Originally *Cardium (Fragum) burnsii* Dall.)
Crassinella triangulata (Dall, 1903), p. 90. (Originally *Crassatellites (Crassinella) triangulatus* Dall, 1900.)
Venericardia hadra Dall, 1903, p. 124.

HEASLIP, W. G., 1968, Palaeontographica Americana, v. 6, no. 39.

Venericardia (Glyptoactis) hadra Dall, p. 116, pl. 29, figs. 2a,b; 3, 4.
(Discussion regarding related species.)

MILLER, A.K., and H. R. DOWNS, 1950, Jour. Paleontology, v. 24, no. 1.

Aturia curvilineata Miller and Thompson, p. 12, pl. 10, figs. 4-7.
(First record of occurrence in the Chipola Formation.)

OLSSON, A. A., 1964, Neogene Mollusks from northwestern Ecuador. Paleontological Research Institution.

Polystira albidoides Gardner , p. 90, pl. 19, fig. 5; no discussion.
Glyphostoma locklini Olsson, n. sp., p. 109, pl. 19, figs. 7-7b.

OLSSON, A. A., 1965, Bulls. Amer. Paleontology, v. 49, no. 224.

Falsilyria pycnopleura (Gardner), p. 665, pl. 83, fig. 8; figure only.

OLSSON, A. A., 1967, Some Tertiary Mollusks from South Florida and the Caribbean. Paleontological Research Institution.

Cirsotrema (Cirsotremopsis) dalli Rehder, p. 40, pl. 5, figs. 2,2a.
(First record of occurrence in the Chipola Formation.)
Scalina gardnerae Olsson, n. sp., p. 42, pl. 5, fig. 3; pl. 6, figs. 2,2a.

OLSSON, A. A., and R. E. PETIT, 1964, Bulls. Amer. Paleontology, v. 47, no. 217.

Siphocypraea (Siphocypraea) chilona (Dall), p. 560, pl. 83, fig. 6.
(Originally *Cypraea (Cypraeorbis) chilona* Dall.)

PARKER, J. D., 1948, Nautilus, v. 61, no. 3.

Cassis delta Parker, n. sp., p. 91, pl. 6, figs. 1,1a,b. (Together with a discussion of the associated fauna, p. 90-95.)

PETIT, R. E., 1970, Tulane Stud. Geol. Paleont., v. 8, no. 2.

Charcolleria distinguenda Petit, n. sp., p. 84, pl. 1, figs. 2a,b.

PILSBRY, H. A. and A. A. OLSSON, 1954, Bulls. Amer. Paleontology, v. 35, no. 152.

Falsilyria pycnopleura (Gardner), p. 21, pl. 3, fig. 1. (Originally *Lyria pycnopleura* Gardner.)
Enaeta americana (Dall), p. 24, pl. 3, fig. 3. (Originally *Strigatella americana* Dall.)

ROWLAND, H. I., 1936, Amer. Midl. Nat., v. 17, no. 6.

Chlamys (Chlamys) chipolanus (Dall), p. 1006, pl. 7, fig. 4, pl. 9, fig. 3. (Originally *Pecten (Aequipecten) chipolanus* Dall.)
Chlamys (Chlamys) alumensis (Dall), p. 1007, pl. 7, figs. 1, 3. (Originally *Pecten (Chlamys) alumensis* Dall.)

[see also TUCKER, H. I., and TUCKER-ROWLAND, H. I.]

STEWART, R. B., 1930, Acad. Nat. Sci. Phila., Spec. Pub. no. 3.

Venericardia (Glyptoactis) hadra Dall, p. 151-152, no figure.
(Sub-genus *Glyptoactis* proposed.)

TUCKER, H. I., 1930, Indiana Acad. Sci., Proc., v. 40.

Pecten (Chlamys) kathrinepalmerae [sic] Tucker, n. sp., p. 244, pl. 1, figs. 2, 5.

TUCKER, H. I., 1936, Amer. Midl. Nat., v. 17, no. 2.

Pecten (Pecten) kathrinepalmerae Tucker, p. 477, pl. 2, fig. 3. (Change in sub-generic assignment.)
Pecten (Pecten) burnsi Dall, p. 478, pl. 4, figs. 3, 4 (after Dall).

TUCKER-ROWLAND, H. I., 1938, Mém. Mus. Royal d'Hist. Nat. de Belgique, ser. 2, fasc. 13.

Chlamys (Lyropecten) madisonius acanikos (Gardner), p. 11, pl. 4, fig. 12, pl. 5, figs. 2, 4. (Reduced to subspecies.)
Chlamys (Lyropecten) condylomatus (Dall), p. 12, pl. 6, figs. 3a, b. (Originally *Pecten (Nodipecten) condylomatus* Dall.)
Chlamys (Lyropecten) sayanus (Dall), p. 13, pl. 2, fig. 6, pl. 6, fig. 1. (Dall's Chipola record repeated; *fide* Gardner, 1926, p. 46, Chipola specimens = *acanikos* Gardner.)
Amusium (Amusium) precursor (Dall), p. 58, pl. 2, fig. 1. (First published illustration.)

VOKES, E. H., 1963, Tulane Stud. Geol., v. 1, no. 3.

Murex (Murex) chipolanus Dall, p. 98, pl. 1, figs. 3a,b. (Redescribed and lectotype figured.)
Murex (Murex) gardnerae E. H. Vokes, n. sp., p. 99, pl. 1, figs. 1a,b.
(For *Murex chipolanus* of Gardner not of Dall)
Murex (Murex) gilli (Maury), p. 100, pl. 2, figs. 1-4. (=*Murex (Murex) dasus* Gardner.)
Murex (Murex?) vaughani Maury, p. 102, pl. 1, figs. 2a,b.
Murex (Murex) nicholsi Gardner, p. 105, pl. 3, figs. 3-5. (First record of occurrence in the Chipola Formation.)

VOKES, E. H., 1963, Tulane Stud. Geol., v. 1, no. 4.

Murex (Bolinus) vaughani Maury, p. 151, pl. 1, figs. 1a,b. (Change in sub-generic assignment.)
Murex (Chicoreus) lepidotus E. H. Vokes, n. sp., p. 152, pl. 1, figs. 2a,b.
Murex (Chicoreus) lepidotus dujardinoides E. H. Vokes, n. subsp., p. 155, pl. 1, figs. 3a,b.
Murex (Phyllonotus) infrequens E. H. Vokes, n. sp., p. 156, pl. 1, figs. 4a,b.

VOKES, E. H., 1964, Tulane Stud. Geol., v. 2, no. 2.

Turbinella dodonaia (Gardner), p. 50, pl. 1, figs. 2a,b,c. (First record of occurrence in the Chipola Formation.)
Turbinella chipolana Dall, p. 58, pl. 2, figs. 1a,b,c.
Turbinella dalli E. H. Vokes, n. sp., p. 59, pl. 2, figs. 2a,b,c.

VOKES, E. H., 1965, Tulane Stud. Geol., v. 3, no. 4.

Chicoreus (Siratus) chipolanus (Dall), p. 183. (Change in generic and sub-generic assignments.)
Chicoreus (Siratus) gardnerae (E. H. Vokes), p. 183. (Change in generic and sub-generic assignments.)
Chicoreus (Siratus) gilli (Maury), p. 183. (Change in generic and sub-generic assignments.)
Chicoreus (Siratus) nicholsi (Gardner), p. 183. (Change in generic and sub-generic assignments.)
Chicoreus (Chicoreus) folidodes (Gardner), p. 184, pl. 1, figs. 1a,b. (Originally *Murex folidodes* Gardner.)
Chicoreus (Chicoreus) lepidotus (E. H. Vokes), p. 185, pl. 1, fig. 4. (Change in generic assignment.)
Chicoreus (Chicoreus) dujardinoides (E. H. Vokes), p. 185, pl. 1, fig. 6. (Change in generic assignment.)
Chicoreus (Chicoreus) cornurectus (Guppy), p. 186, pl. 2, figs. 2a,b, text figure 1. (First record of occurrence in the Chipola Formation.)
Note on the Age of the Chipola Formation (Miocene) of Northwestern Florida, p. 205-208.

VOKES, E. H., 1966, Tulane Stud. Geol., v. 5, no. 1.

Vasum chipolense E. H. Vokes, n. sp., p. 10, pl. 2, figs. 1, 2.
Vasum haitense (Sowerby), p. 10, pl. 3, figs. 1-4; pl. 4, fig. 3, text figure 1. (*Vasum engonatum* Dall = *Vasum haitense* (Sowerby).)

VOKES, E. H., 1967, Tulane Stud. Geol., v. 5, no. 3.

Chicoreus (Phyllonotus) cf. *tritonopsis* (Heilprin), p. 142, pl. 2, fig. 6. (*Incertae sedis* Gardner = *Chicoreus (Phyllonotus)* cf. *tritonopsis* (Heilprin).)
Chicoreus (Phyllonotus) folidodes (Gardner), p. 143, pl. 3, figs. 1a,b. (Change in sub-generic assignment.)
Chicoreus (Phyllonotus) infrequens (E. H. Vokes), p. 143, pl. 1, figs. 10a,b. (Change in generic assignment.)

VOKES, E. H., 1968, Tulane Stud. Geol., v. 6, no. 3.

Hexaplex (Hexaplex) veatchi (Maury), p. 101, pl. 3, figs. 3a,b, 5. (Originally *Murex veatchi* Maury.)
Murexiella (Murexiella) calhounensis E. H. Vokes, n. sp., p. 110, pl. 5, figs. 4a,b.
Murexiella (Murexiella) shilohensis (Heilprin), p. 110, pl. 6, figs. 2-4. (First record of occurrence in Chipola Formation.)
Murexiella (Subpterynotus) textilis (Gabb), p. 120, pl. 8, figs. 1-3. (First record of occurrence in Chipola Formation.)

VOKES, E. H., 1970, Tulane Stud. Geol. Paleont., v. 8, no. 1.

Pterynotus (Pterynotus) hoerlei E. H. Vokes, n. sp., p. 12, pl. 2, figs. 3a,b.
Poirieria (Panamurex) laccopoia (Gardner), p. 31, pl. 7, figs. 1a,b. (Originally *Muricopsis laccapoia* Gardner.)

Poirieria (Panamurex) fusinoides (Gardner), p. 34, pl. 6, figs. 9a,b. (Originally *Paziella (Dallimurex) fusinoides* Gardner.)
Poirieria (Panamurex) lychnia (Gardner), p. 35, pl. 6, figs. 5a,b. (Originally *Paziella (Dallimurex) lychnia* Gardner.)
Poirieria (Panamurex) mauryae E. H. Vokes, n. sp., p. 36, pl. 6, figs. 8a,b.
Chicoreus (Siratus) juliagardnerae E. H. Vokes, p. 51. (New name for *Murex gardnerae* Vokes *non Alectrion gardnerae* Dall, which = *Chicoreus (Phyllonotus) trophoniformis* (Dall).)

VOKES, E. H., 1970, Tulane Stud. Geol. Paleont., v. 8, no. 2.

Vasum tribulosum E. H. Vokes, n. sp., p. 90, pl. 1, figs. 1a,b.
Vasum elongatum E. H. Vokes, n. sp., p. 92, pl. 1, figs. 2a,b.

VOKES, H. E., 1969, Tulane Stud. Geol. Paleont., v. 7, no. 3.

Miltha (Miltha) chipolana (Dall), p. 118-121, pl. 1, fig. 3; pl. 2, figs. 4a,b; pl. 3, figs. 1a-d, 2a-d; pl. 5, figs. 1-6; text fig. 1. (Originally *Phacoides (Miltha) chipolanus* Dall.)
Eomiltha scolaroi H. E. Vokes, n. sp., p. 128, pl. 1, figs. 1-7.

VOKES, H. E. and E. H. VOKES, 1968, Tulane Stud. Geol., v. 6, no. 2.

Orthaulax gabbi Dall, p. 74-76, pl. 1-3.

WOODRING, W. P., 1964, U.S.Geol. Surv. Prof. Paper 306-C.

Pallacera chipolanus (Dall), p. 269. (Originally *Phos (Strongylocera) chipolanus* Dall.)
Pallacera pedanus (Gardner), p. 269. (Originally *Phos (Strongylocera) pedanus* Gardner.)

WOODRING, W. P., 1970, U.S. Geol. Surv. Prof. Paper 306-D.

Eulima acuta Sowerby, p. 327, pl. 51, fig. 13. (Misidentified by Gardner as *Strombiformis scotti* (Maury).)
Pleuroliria (Polystria) albidoides (Gardner), p. 363. (Originally *Polystira albidoides* Gardner.)
Cytharella compsacosta (Gardner), p. 392. (Originally *Ithycythara compsacosta* Gardner.)
Cytharella cryptopleura (Gardner), p. 393. (Originally *"Mangelia" cryptopleura* Gardner.)
Cytharella chariessa (Gardner), p. 393. (Originally *"Cythara" chariessa* Gardner.)
Cytharella barbadoides (Gardner), p. 393. (Originally *"Cythara" barbadoides* Gardner.)
Cytharella isabellae (Maury), p. 393. (In Gardner as *"Cythara" isabellae* (Maury).)
Roxania chipolana (Dall), p. 419, pl. 62, fig. 14. (In Gardner as *Abderospira chipolana* (Dall).)
Florabella aldrichi (Dall), p. 420, pl. 50, figs. 1, 2, 5-8. (Originally *Dolabella aldrichi* Dall.)
Volvulella (Volvulella) oxytata (Bush), p. 425, pl. 62, figs. 19, 20. (Originally *Volvula oxytata* Bush.)

* * * * * * * * * *

In addition to the predominantly molluscan reports, certain papers on other phyla have appeared, which are of special interest.

PHYLUM *BRYOZOA*

SCOLARO, R. J., 1970, Tulane Stud. Geol. Paleont., v. 8, no. 2.

Discoporella umbellata depressa (Conrad), p. 96, text fig. 2. (First record of occurrence in the Chipola Formation.)

PHYLUM *COELENTERATA*

WEISBORD, N. E., 1971, Florida Geol. Surv., Bull. 53.

Thirteen species of corals from the Chiopla Formation discussed and figured, eight of which are new.

PHYLUM *PROTOZOA*

AKERS, W. H., 1972, Tulane Stud. Geol. Paleont., v. 9, (nos. 1-4).

Eight species of planktonic foraminifera from the Chipola Formation described and figured.

PURI, H. S., 1953, Florida Geol. Surv., Bull. 36.

Fifty-three species of Chipola foraminifera listed, of which nine are not specifically identified.

PHYLUM *ARTHROPODA*

PURI, H. S., 1953, Florida Geol. Surv., Bull. 36.

Twenty species of Chipola ostracods discussed, of which eight are described and figured as new species.

November 28, 1972

REVIEW

TOWARD A HISTORY OF GEOLOGY, edited by Cecil J. Schneer; the proceedings of the New Hampshire Inter-Disciplinary Conference on the History of Geology, September 7-12, 1967. Published by The M.I.T. Press, Cambridge, Massachusetts, and London, England, 1970, vi + 469 pp., $22.50

The participants in the New Hampshire Conference are leading scholars in various fields of the history of the geological sciences. In his introduction, Professor Schneer states: "It is the purpose of this Conference and this volume to reconstruct the intellectual climate within which our science evolved—to recreate the world view that was available to young Charles Darwin, out of which the theory of evolution was to emergy." The 26 papers presented and published here reveal and illustrate quite well the breadth and scope of the present knowledge of this intellectual climate as it existed in the early nineteenth century. Among the papers are studies of American and Russian geology as well as English and continental geology. Also, summary articles on certain aspects of geologic thought during the eighteenth century and on major scientific figures such as Alexander von Humboldt, Geoffroy Saint-Hilaire, and Benoit de Maillet are included. All of the papers are significant contributions to the literature of the history of science and many contain valuable reassessments of the role of certain individuals in the development of geologic thought in the early decades of the nineteenth century. Some deal with little known contributions, previously generally overlooked by historians. Among these, some surprises await the reader such as extensive discussion of de Maillet's ideas on marine processes and his emphasis on the action of the sea in an era when the field of oceanography was unknown or nonexistent, and his belief that "diminution of the sea" and, thus, earth history has an antiquity in the order of two billion years!

Minor criticisms felt by this reviewer are that some authors focus their attention a bit too strongly and overstate the significance of the contributions of certain individuals and that there is a tendency to overcompensate for the frailty of the "Great Man" approach to historical analysis. It is suggested that the "game" of searching out who was actually first to state a concept is secondary in importance to the determination of who made the statement that actually was read and comprehended by his contemporaries and how much real influence that statement exerted on the progress of geologic thought.

H.C.S.

RECENT BOOKS RECEIVED

THE THEORY OF GROUND-WATER MOTION AND RELATED PAPERS, by M. King Hubbert. Published by Hafner Publishing Company, New York and London, 1969, 311 pp., illus., $12.50

DICTIONARY OF FUEL TECHNOLOGY, by Alan Gilpin. Published by Philosophical Library Inc., New York, 1969, xii + 275 pp., $20.00

QUARRYING, OPENCAST AND ALLUVIAL MINING, by John Sinclair. Published by Elsevier Publishing Company, Ltd., Amsterdam, London and New York, 1969, vii + 375 pp., illus., $21.50

RUTLEY'S ELEMENTS OF MINERALOGY, the twenty-sixth edition, by H. H. Read. Published by Thomas Murby & Co., London, 1970, xii + 560 pp., illus.

CREUSIA NEOGENICA, A NEW SPECIES OF CORAL-INHABITING BARNACLE FROM FLORIDA

NORMAN E. WEISBORD

DEPARTMENT OF GEOLOGY,
FLORIDA STATE UNIVERSITY, TALLAHASSEE

While working on the collection of Florida invertebrates in the Department of Geology at Florida State University, the writer came upon an unlabeled specimen of stony coral in which are imbedded a number of unusual barnacles. Since there is no information of any kind concerning the specimen, it is the purpose of this paper to determine, from indirect evidence, the locality and geologic age of the host, and to describe the barnacle which inhabits it.

I have compared the coral in question with specimens of *Siderastrea pliocenica* Vaughan from the Caloosahatchee River, Florida, in both the United States National Museum and the Academy of Natural Sciences of Philadelphia, and it seems to be identical with that species. The barnacle, however, although close to *Pyrgoma prefloridanum* Brooks and Ross, is believed to be new, and for it the name *Creusia neogenica* is proposed. The generic classification as *Creusia* accords well with recent diagnoses of that taxon. The particular species is characterized by its distinct external radii, and is the first *Creusia* with such radii to be reported from the contiguous United States.

Over ten individuals of *Creusia neogenica* are domiciled in the corallum of *Siderastrea pliocenica:* six of them occur in a cluster with their compartments touching, and the largest and best preserved of these is designated the type. Partially or wholly, it is the shell or crown of the barnacle that protrudes through the surface of the corallum, and it is the elongated conical basis that is imbedded, generally in its entirety, within the corallum. In places even the orifice of the barnacle may be veneered over by the calicular surface of the host.

The coral *Siderastrea pliocenica* was reported by Vaughan from the Caloosahatchee River and Shell Creek in southern Florida, and it is suggested that the unlabeled specimen was also found somewhere in southern Florida. Evidence to support the assumed, but not necessarily exclusive South Florida occurrence, is the discovery by Joseph E. Banks of what I identify as *Siderastrea pliocenica* Vaughan in the Pinecrest Sand about four miles east of U.S. 301, Sarasota, Florida, in the Warren Brothers Pits. The particular specimen donated by Mr. Banks bears three deep conical cavities, not now containing, but suggesting the former presence of imbedded barnacles.

The age of Vaughan's Caloosahatchee Marl is not known with certainty as the term Caloosahatchee is today used in the sense of Group, and consists of a number of formations ranging in age from late Miocene to Pleistocene or Subrecent. In his "Caloosahatchee Marl," Vaughan (1919, p. 22) listed 19 species of corals, among them *Siderastrea pliocenica.* If all of Vaughan's corals came from a single formation its age would be pre-Pleistocene because 6 or 7 of the 19 corals have not survived to Recent time; were the corals Pleistocene, most or all of them would be living in the present. However, Dr. Emily Vokes (personal communication) suggests that Vaughan's "Caloosahatchee Marl" included both what is now termed the Caloosahatchee Formation and the Glades deposit which overlies it. Olsson (1969, pp. 125-133) considers the Caloosahatchee Formation as Pliocene and the Glades as Plio-Pleistocene. *Pyrgoma prefloridanum* Brooks and Ross occurs in both the Caloosahatchee Formation and Glades deposit, inhabiting the coral *Mani-*

cina areolata (Linnaeus). The coral *Siderastrea pliocenica* Vaughan occurs in both the Caloosahatchee Formation (Pliocene) and the Pinecrest beds (Mio-Pliocene)

According to Olsson and Petit (1964) who first described the unit, the "Pinecrest beds" immediately underlie the Caloosahatchee Formation and are late Miocene or Pliocene in age. Brooks *in* Eppert (1966), and Eppert (1966) recognized the presence of upper Miocene deposits in Sarasota County and referred to them as a lithosome of the Tamiami Formation. Hunter (1968), on the basis of certain distinctive species of *Pecten* and other mollusks, established the concurrent range zones of the Pinecrest Sand, Ochopee Limestone, and Buckingham Limestone in the upper part of the Tamiami Formation (upper Miocene), and stated that the Tamiami is probably equivalent to the Jackson Bluff Formation of North Florida, to the Duplin Marl of South and North Carolina, and to the Yorktown Formation of Virginia. Puri (1970-71, personal communication), who has also furnished me with corals from the Pinecrest Formation in the Warren Brothers Pits, measured and described the section there in mid-1970. That section and the fossil identifications as determined by Puri are reproduced below.

WARREN BROTHERS PITS

Sarasota, Florida

4.5 miles east off U.S. 301, 17th Street, dead-end, turn left on paved road [Newburn Rd.], go 0.4 miles, pits on right.

BED	DESCRIPTION	THICKNESS [Ft.]
4	Pleistocene Sand	+15
	Pinecrest Formation	
3	Oyster Biostrome, as bed 1 (delicate) *Pecten* sp., *Ostrea haitensis* (Sowerby) mostly articulated valves, *Conus,* sp.	4
2	Shell hash, sandy with few complete mollusks; top of the bed marked with *Mytiloconcha* sp. oriented as in life. Can be traced laterally around the pits.	1
1	Oyster Biostrome Light gray to green shell hash, quartz sand with *Ostrea haitensis* (Sowerby), *Pecten eboreus darlingtonensis* Dall, *Cancellaria propevenusta* Mansfield, *Murex globosus* Emmons, *Conus adversarius* Conrad.	3

The corals collected by Joseph E. Banks (including *Siderastrea pliocenica)* and by Harbans Puri occur in the oyster biostromes.

DESCRIPTION OF SPECIES

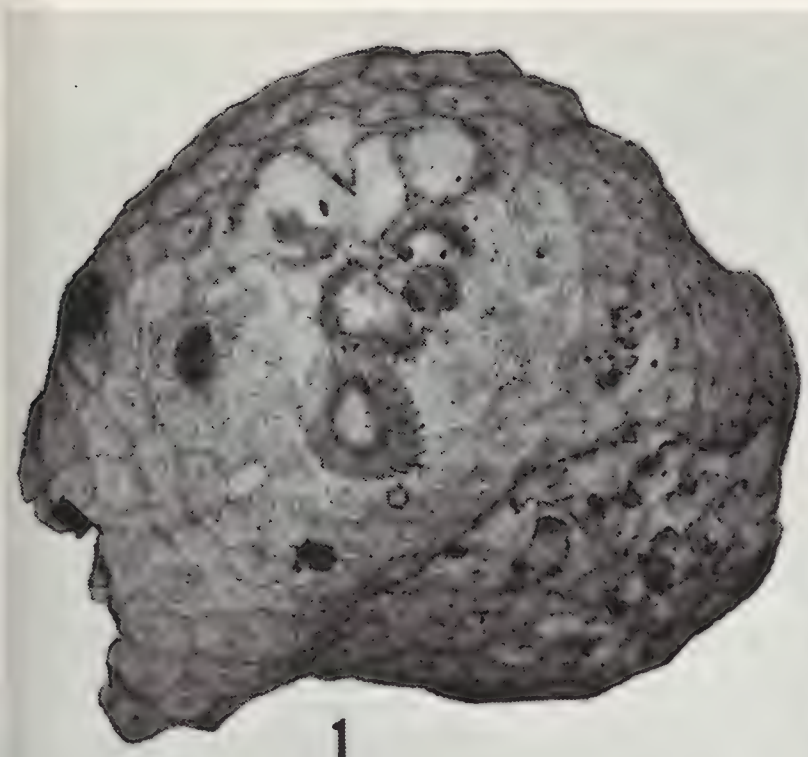
Family BALANIDAE Leach 1817

Subfamily CREUSIINAE Baluck and Radwanski, 1967

CREUSIA NEOGENICA Weisbord, n.sp.

Description: The barnacle *Creusia neogenica* is domiciled in the coral *Siderastrea pliocenica* Vaughan (1919, pp. 437, 441, 442, pl. 118, figs. 2,2a,2b,3). The shell or crown of the barnacle protrudes through the surface of the coral, but the basis is imbedded well within it. The shell is light tan in color, small, depressed-domal, broadly ovate in outline, and flattish above. The orifice is large and obtusely diamond-shaped, its length a little over half that of the shell. The compartments slope gently from the orifice but then steepen to nearly vertical at the basis, the basis separated from the shell proper by a fine but distinct seam. The basis itself is regularly conical and moderately long.

Figures 1-5. *Creusia neogenica* Weisbord, n.sp., imbedded in the coral *Siderastrea pliocenica* Vaughan. Fig. 1, about natural size, showing a cluster of *Creusia neogenica.* The type is the entire barnacle near the center of the corallum of *Siderastrea pliocenica.* Fig. 2, the same cluster of barnacles enlarged 4 X. The inner wall of the basis is shown in the specimen top center. Fig. 3, type enlarged 4.5 X, showing position of external radii. Fig. 4, type enlarged 5.5 X, showing growth laminations, internal sutures, and seam at the base. Fig. 5, enlarged 4.5 X, side view of type showing character of the seam. The specimen abutting the type on the left shows the sturdy laminae that connect the sheath (not present) to the wall. The specimen to the far left is the same as that in the top center of Figure 2, and shows the character of the internal ribs of the basis.



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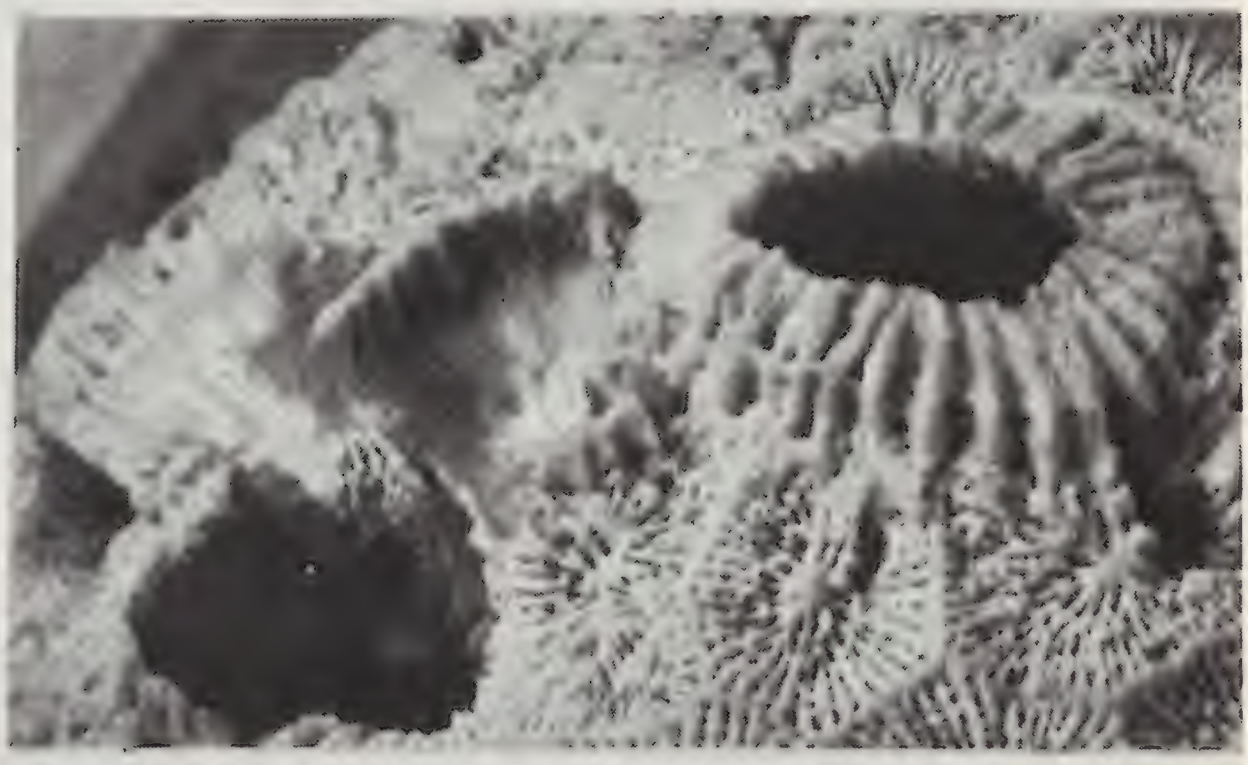

5

The four compartments are strongly ridged, the ridges radiating from the orifice. On the type there are 7 ridges on the carina and each of the lateral parietes, and 10 on the rostrum, or 31 in all not counting the ridge-like prolongation on the lower half of each radius. On immature specimens as few as 24 such ridges have been counted. The ridges are coarse, subequal, separated below by deep and wide interspaces, and rendered scabrous by concentric growth laminations which are arched upward in the interspaces but pointed sharply downward on the crest of the ridges.

The four external radii are not uniform although each of them is relatively small, horizontal at the summit, and traversed by prominent transverse riblets. The two radii on one side of the shell are broader than the two on the other. The anterior of the two broader radii is triangular, extends half way down the compartment, and is divided by a sulcus into two unequal segments, the larger prolonged below into a ridglet smaller than but similar to the ridges of the parietes. The posterior of the two broader radii is wedge-shaped and slightly convex, and extends two-thirds down from the orifice, the sides converging to form the radius ridglet below. The narrow anterior and posterior radii on the opposite side of the shell are divided by a fine, hardly perceptible, longitudinal incision, and extend down the compartment to near the seam where they merge with the nearest parietal ridge. On one shell other than the type, the narrow furrows between the transverse riblets of the radius are porose, the pores aligned in a single column on both sides of the smaller segment of the radius.

The clefts or sutures separating the compartments are seen on the underside of the radii just below the rim of the orifice along the alar edge of the sheath.

On the type, the sheath is thick and extends to about the basal margin of the compartments or to the seam which differentiates the shell from the basis; its height therefore is about the same as that of the shell but only one seventh of the shell and basis combined. In another specimen the sheath is about 2.5 mm high and extends part way down the basis. Except for the connective laminae, the lower portion of the sheath is free, leaving a space between it and the wall behind. The frontal surface of the sheath is scored by raised, closely spaced, subregular, concentric straie. The inner wall of the compartments back of the sheath is made up of broad, slightly raised, hollow longitudinal ribs, these extending well down the basis; they are gently concave along the middle and are crossed by irregularly spaced partitions, the ribs thus resembling the inner half of a shoot of bamboo, split lengthwise. Between each of the internal ribs is a narrow groove or furrow, and nestled into each groove is a sturdy lamina projecting thereto from the back of the sheath; each lamina in turn connects through the wall with its respective external ridge on the outer surface of the parietes. The internal ribs extend to near the lower end of the basis which is thickly calcified and smooth, the original aperture at the bottom having been sealed over by carbonate deposit. The external surface of the basis—that is of the surface in contact with the coral—consists of prolongations of the same ridges that are present on the shell.

The opercular valves have not been recovered.

Measurements. The type specimen of *Creusia neogenica* is the largest and most complete of those in the cluster, and has the following dimensions: length of shell proper 9 mm, maximum width 7.8 mm, height from apex to seam 1.2 mm.; length of orifice 5 mm, maximum width 3.8 mm.; total height of shell and basis about 8 mm. The corallum of *Siderastrea pliocenica* is 50.5 mm in length, 46 mm in width, and 36 mm in height.

Type specimen. The coral and the barnacles inhabiting it are designated FLX-12. Present repository is the Department of Geology, Florida State University.

Comparisons: The relatively large orifice, the small but distinct external radii, and the strong, nearly equal radial ridges on the parietes are distinguishing characters of the new species. The four compartmental plates (visible in the interior) and the presence of four external radii on the exterior of the shell are indicative of the genus *Creusia* (see Baluk and Radwanski, 1967; and Newman, Zullo, and Withers, 1969, p. R287, fig. 18A, nos. 15a,b).

Creusia neogenica, n. sp., resembles the cosmopolitan and variable *Creusia spinulosa* Leach (see Darwin, 1854, pp. 376-382) but differs from all of the variants of that species in having a larger orifice, and from some of the variants in its coarse parietal ridges of nearly equal size. Another similar species is *Creusia barbadensis* Withers (1926) from the Pleistocene of Barbados, but the Barbados form is smaller, subcircular rather than subovate in outline, and with parietal ridges that are less regular in size than on *Creusia neogenica.* Externally the shell of both species seems to be formed of a single sutureless piece, but

unlike older shells of *C. barbadensis* the Floridan *C. neogenica* does not exhibit the two external sutures at the carinal end.

So far as I am aware there are only two coral-inhabiting barnacles in the subfamily Creusiinae reported from the United States, and both of them are from Florida. The first is the Recent *Pyrgoma floridanum* Pilsbry (1931) from off the west coast of Florida, and this differs from *Creusia neogenica* in showing "no traces of radii or sutures" on the exterior, in having a smaller and more ovate orifice, and in having fewer (28) and narrower radial ridges on the compartments of an adult specimen 9 mm in diameter.

The second related species is the Neogene *Pyrgoma prefloridanum* Brooks and Ross from the Bee Branch Member of the Caloosahatchee Group of Florida. *Pyrgoma prefloridanum* inhabits the coral *Manicina mayori* (Wells) [= *Manicina areolata* (Linnaeus) *fide* Wells *in* Weisbord, 1968, p. 52], and as there is a large specimen of *Manicina areolata* in the Florida State University collection from the Caloosahatchee River "2-5 miles west of La Belle" with more than 30 individuals of *Pyrgoma prefloridanum* imbedded in it, a direct comparison between *Creusia neogenica* and *Pyrgoma prefloridanum* can be made. There is considerable resemblance between the two species of barnacles although important differences are also discernible. First, Brooks and Ross do not mention or illustrate, nor have I observed, external radii on *Pyrgoma prefloridanum*, whereas they are a distinct feature of *Creusia neogenica.* Second, *P. prefloridanum* inhabits the coral *Manicina* but *C. neogenica* is domiciled in the coral *Siderastrea,* and since the corals are wholly dissimilar, the selectivity of the barnacle species may also be related to their genetic differentiation. Third, although both barnacle species are marked by strong radial ridges on the parietes, those of *P. prefloridanum* are intercalated by secondary ones whereas the ridges of *C. neogenica* are all primaries and nearly equal in size. Unfortunately the opercular valves cannot be compared as they have not been recovered from *Creusia neogenica.*

Baluk and Radwanski (1967) place *Pyrgoma floridanum* and *Pyrgoma prefloridanum* in the genus *Creusia* Leach, and assign to *Creusia* a geologic range of Miocene to Holocene. The same authors place *Pyrgoma* Leach *s.s.* in a taxon in which the shell is constructed of a single compartment, and state that there are four known species, all of them Recent.

Coral hosts: Both the Recent *Pyrgoma floridanum* Pilsbry and the Neogene *Pyrgoma prefloridanum* Brooks and Ross are domiciled in the coral *Manicina,* probably *Manicina areolata* (Linnaeus) which ranges from Miocene to Recent. *Creusia neogenica,* n. sp., inhabits the coral *Siderastrea pliocenica* Vaughan of late Miocene to Pliocene age. *Creusia sanctacrucensis* Baluk and Radwanski (1967, p. 470), a Miocene barnacle from central Poland, is found imbedded in the coral *Tarbellastrea reussiana* (Edwards and Haime). Another coral-inhabiting barnacle, *Balanus (Hexacreusia) durhami* Zullo (1961), ranging in age from Pleistocene to Recent, occurs in the Gulf of California region of Mexico, and resides in the coral *Porites.* The subgenus *Hexacreusia* is a six-plated balanid with solid parietes and radii.

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I wish to express my appreciation to Dr. Emily Vokes of Tulane University for her careful review of the manuscript and for sending me certain coral-inhabiting barnacles which enabled me to insure the validity of the new species. I also wish to thank Dr. Fritz Cramer of the Department of Geology, Florida State University and Gerrit Mulders of Tallahassee for the photographs accompanying this paper.

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NORMAN O. FREDERIKSEN
DEPARTMENT OF GEOLOGY
CALIFORNIA STATE UNIVERSITY, SAN DIEGO

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I. ABSTRACT

Twenty-two new species of spores and pollen grains are described from upper middle Eocene, upper Eocene, and lower Oligocene strata of Mississippi and western Alabama. The species are assigned to three modern and 18 fossil genera. All the species but one range at least from the base to the top of the Yazoo Clay (upper Eocene), and 14 of them range at least from the middle Eocene to the lower Oligocene. *Betulaceoipollenites* Potonié and *Navisulcites* Anderson are considered, respectively, to be junior synonyms of *Trivestibulopollenites* Pflug and *Monosulcites* Couper. *Echiperiporites* van der Hammen and Wymstra is emended to include stephanoporate forms.

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II. INTRODUCTION

A number of new species of spores and pollen grains were encountered by the writer during a study of mid-Tertiary palynomorphs from the eastern Gulf Coast (Frederiksen, 1969). Engelhardt (1964a) illustrated and briefly discussed a number of spore and pollen types from the upper middle Eocene Cockfield Formation of Mississippi, but, with one exception (Engelhardt, 1964b), he made no attempt to name new species. Tschudy and van Loenen (1970) illustrated many spores and pollen grains from the upper Eocene Yazoo Clay of Mississippi, also without naming any new species. Many of the new forms found by the writer range at least from the upper middle Eocene to the lower Oligocene, and the species will also be found by other

TABLE 1

List of localities sampled (M.G.S. = Mississippi Geological Survey).

Western Mississippi:

1. Yazoo City, M.G.S. borehole in SE 1/4, SW 1/4, SE 1/4, sec. 32, T12N, R2W, Yazoo County, Miss. Type locality of the Yazoo Clay.
2. M.G.S. borehole AF-40, SW 1/4, SE 1/4, NW 1/4, sec. 5, T7N, R1W, Hinds County, Miss.
3. Forest Hill, M.G.S. borehole AF-8, SE 1/4, SE 1/4, NE 1/4, sec. 22, T5N, R1W, Hinds County, Miss. Type locality of the Forest Hill Sand.
4. Near Cynthia, clay pit of the Jackson Ready-Mix Concrete Company, SW 1/4, NE 1/4, NW 1/4, sec. 36, T7N, R1W, Hinds County, Miss.
5. Riverside Park in Jackson, Hinds County, Miss. Cockfield Fm. sampled from outcrop, Moodys Branch Fm. and Yazoo Clay from M.G.S. borehole AF-17. Reference locality for the Moodys Branch Fm.

Eastern Mississippi:

6. Near Rose Hill, M.G.S. borehole in NE 1/4, NE 1/4, NE 1/4, sec. 11, T3N, R12E, Jasper County, Miss. Near the type locality of the North Twistwood Creek Clay Member of the Yazoo Clay.
7. Barnett, M.G.S. borehole in SW 1/4, NE 1/4, sec. 30, T2N, R14E, Clarke County, Miss. Near the type locality of the Pachuta Marl Member of the Yazoo Clay.
8. Near Hiwannee, cutbank on the east side of the Chickasawhay River, NE 1/4, SW 1/4, sec. 28, T10N, R7W, Wayne County, Miss. Reference locality for the Red Bluff Clay.
9. Shubuta Hill, outcrop in S 1/2, SW 1/4, sec. 3, T10N, R7W, Clarke County, Miss. Type locality of the Shubuta Clay Member of the Yazoo Clay.
10. Shiloh Creek, roadcut and banks of the creek in SW 1/4, sec. 18, T10N, R5W, Wayne County, Miss.

Western Alabama:

11. Little Stave Creek, off the west side of U.S. Highway 43, 3.5 miles north of Jackson, Clarke County, Ala.

palynologists in these strata. Thus it seems worthwhile to describe and name the more abundant of the new species, and 22 of them are described and illustrated here.

The specimens are from the upper Claiborne Stage (middle Eocene), the Jackson Stage (upper Eocene), and the lower Vicksburg Stage (lower Oligocene) of Mississippi and western Alabama. The study is based on 72 outcrop and core samples. Counts were made of 56 of these samples, and at least one slide from each sample was completely scanned. Partial scans were made of the other 16 samples. The 72 samples represent three sections: (1) a composite section of the upper Claiborne-lower Vicksburg from five localities in western Mississippi, (2) a composite section of the lower Jackson-lower Vicksburg from five localities in eastern Mississippi, and (3) the long section of upper Claiborne-lower Vicksburg exposed in the banks of Little Stave Creek in Clarke County, Alabama. The mid-Tertiary stratigraphy of this area was summarized by Murray (1961, p. 379-398). The localities sampled by the writer were described by the Mississippi Geological Society (1948, Stops 8, 9 and 14); Moore (1965, p. 50, 117 and 132; figs. 9 and 16-17); Moore *et al.* (1964, figs. 13-14); Rainwater (1960); Southeastern Section, Geological Society of America (1964, p. 8); and Toulmin (1962). Table 1 lists the localities and Table 2 the units that were sampled. The Cockfield and Forest Hill formations were only partially sampled—only the upper five feet of the Cockfield Formation, and only the lower 40 feet of the Forest Hill Formation. The other formations listed in Table 2 were sampled from top to bottom.

TABLE 2

Provincial stages, formations, and members that were sampled (in descending order). Numbers in parentheses show the localities where each unit was sampled (from Table 1).

Western Mississippi	*Eastern Mississippi and Western Alabama*
Lower VICKSBURG STAGE	Lower VICKSBURG STAGE
Forest Hill Sand (3)	Red Bluff Clay (8, 11)
JACKSON STAGE	JACKSON STAGE
Yazoo Clay (1, 2, 3, 4, 5)	Yazoo Clay
	Shubuta Clay Mbr. (8, 9, 11)
	Pachuta Marl Mbr. (7, 9, 11)
	Cocoa Sand Mbr. (10, 11)
	North Twistwood Creek
	Clay Mbr. (6, 7, 11)
Moodys Branch Fm. (5)	Moodys Branch Fm. (6, 7, 11)
Upper CLAIBORNE STAGE	Upper CLAIBORNE STAGE
Cockfield Fm. (5)	Gosport Sand (11)

III. ACKNOWLEDGMENTS

Most of the samples were processed by Mobil Research and Development Corporation, Dallas, Texas. R. T. Clarke, W. S. Drugg, L. J. Maher, Jr. and R. H. Tschudy improved this paper by their helpful suggestions. Thanks are also given to the Mississippi Geological Survey for making their cores available for study and sampling.

IV. TECHNIQUES AND METHODS

The samples were processed with cold, concentrated HCl; then with 70 percent HF; washed several times with solutions of Darvan 4 or Joy household detergent to break down and remove fine organic matter; treated briefly with concentrated HNO_3 or HNO_3 plus $KClO_3$; washed with weak NH_4OH; and centrifuged twice in $ZnCl_2$ solution (s.g. 1.65-2.0). The float fraction was stained with Safranin 0 and mounted on cover slips with Clearcol or Natrosol; the cover slips were cemented to slides with Paraplex or Elvacite 2044.

The coordinates listed in the holotype descriptions and the plate captions locate the specimens on the writer's Zeiss microscope. Each slide has an X scratched on it just to the right of the cover slip, and the coordinates of the center of the X, according to the writer's microscope, are written on the slide label. The coordinates may thus be converted so that the specimens can be located easily on any microscope with standard millimeter stage scales. All of the slides are in the writer's collection.

Relative abundances are based on a minimum count of 100 pollen grains and spores (mainly 150-200 grains; one sample of uppermost Yazoo Clay from Forest Hill, western Mississippi, contained only 57 grains). The relative abundances are expressed in terms of categories that are defined in Table 3 ("infrequent," "occasional," etc.) to emphasize that they are only rough estimates of the true relative abundances of each species in the strata.

Data on the range of each species in this paper include information from Engelhardt (1964a), who illustrated the assemblage from the upper Cockfield Formation at Jackson, Mississippi (the writer's locality 5). Unless otherwise stated, each species was observed in all three sections: western Mississippi, eastern Mississippi and western Alabama.

TABLE 3

Definitions of relative abundance terms.

Designation	Definition
"Infrequent"	1%
"Occasional"	1-5%
"Common"	6-20%

V. SYSTEMATIC DESCRIPTIONS

Twenty-two new species are described in this paper. Each new name is based on at least ten specimens unless otherwise noted. In the descriptions, the word "design" is used to designate the pattern on the exine that one sees in plan view. For instance, many tegillate exines appear punctate or granulate in plan view even though the surface of the exine may be smooth (grana are smaller than coni, verrucae, etc. but larger than puncta, and they give an LO-effect; puncta are ≤ 0.5 micron in diameter and give an LO- and (or) an OL-effect). The appearance of the exine in optical section is also described. The grain sizes are mostly averages of several measurements made on each grain. In triangular grains the three axes of the triangle were measured and averaged; in round or nearly round grains the long and short axes were averaged. For oval grains "size" means the length of the long axis. The size measurement includes the ornamentation unless otherwise stated.

Most of the new species described in this paper are assigned to form- and organ-genera. However, several of the new species can be assigned with some confidence to

extant genera, and in these cases the name of the modern genus is used as part of the name of the fossil species. For instance, it seems more reasonable to use the name *Myrica propria* n. sp. than to name the species *Triatriopollenites proprius* n. sp. and then to remark that the species was undoubtedly produced by plants of the genus *Myrica*. However, no attempt is made to transfer similar species described in the literature to *Myrica* or to some other extant genus.

Genus CONCAVISPORITES Pflug
in Thomson and Pflug, 1953

CONCAVISPORITES STAVENSIS
Frederiksen, n. sp.

Pl. 1, figs. 1-4

Description: Size 30-37 microns, mean 34 microns, holotype 36 microns. Outline triangular, with flattened to rather pointed corners and concave sides. Trilete, sutures usually slightly open, rarely with lips, slightly wavy to straight, extending 3/4 to nearly full radius. Exine 2-2.5 microns thick, thickened little if any along the sides; psilate on the outer surface; inner surface of exine with an irregular network of grooves, especially on the inner surface of the distal? face, and normally including a groove that is parallel with the outline.

Holotype: Pl. 1, fig. 1, slide 10558 A-1, 35.7 x 123.1, Gosport Sand at Little Stave Creek, Clarke County, Alabama.

Remarks: In *Concavisporites praeobtusangulus* Krutzsch, 1959a, the exine appears to be thickened midway along the sides. The botanical affinity of *C. stavensis* is unknown, possibly Gleicheniaceae.

Occurrence: The known range is from the lower Gosport Sand to the lower Forest Hill Sand and the lower Red Bluff Clay; "infrequent" in 16/56 counted samples.

Genus LYGODIUM Swartz, 1801

LYGODIUM? LABRATUM
Frederiksen, n. sp.

Pl. 1, figs. 5-10

Description: Size 29-42 microns, mean 35 microns, holotype 34 microns. Outline triangular; sides slightly convex to slightly concave. Trilete; sutures closed, labra 1.5-3 microns wide, rays straight, extending nearly full radius. Exine about 2 microns thick, sexine:nexine 2-3:1. Entire exine foveolate except labra; foveolae 0.5-1 micron in diameter, some of them anastomosing.

Holotype: Pl. 1, figs. 5-6, slide 10656 A-2, 21.2 x 118.0, Yazoo Clay near Cynthia, Hinds County, Mississippi.

Remarks: Foveotriletes scrobiculatus (Weyland and Krieger, 1953) Potonié, 1956, is more densely foveolate. *F. rueterbergensis* Krutzsch, 1962, appears to lack labra. The epithet *labratum* (Latin, "having lips") refers to the presence of labra. *Lygodium? labratum* is similar to spores of *Lygodium flexuosum* (L.) Swartz illustrated by Bolkhovitina (1961, pl. 23, figs. 5a-c). However, the natural affinity of this new species cannot be definitely determined.

Occurrence: The known range is from the upper Gosport Sand to the top of the Yazoo Clay; "infrequent" in eight or nine counted samples; not observed in samples from eastern Mississippi.

Genus UNDULATISPORITES Pflug
in Thomson and Pflug, 1953

UNDULATISPORITES ELSIKII
Frederiksen, n. sp.

Pl. 1, figs. 11-12, 18

Undulatisporites sp. ELSIK, 1968, Pollen et Spores, v. 10, p. 294, pl. 8, fig. 4; pl. 10, fig. 6.

Description: Size 22-47 microns, mean 30 microns, holotype 32 microns. Outline triangular, with convex to slightly concave sides and narrowly rounded corners. Trilete; sutures closed; labra wavy, 0.5-1 micron wide and about 3 microns high, extending nearly to the outline. Exine 1-1.5 microns thick, psilate or rarely infrapunctate, sometimes with one or two coarse folds.

Holotype: Pl. 1, fig. 18, slide 10529 A-1, 31. 3 x 111.7, Red Bluff Clay near Hiwannee, Wayne County, Mississippi.

Remarks: This species is distinguished by its high labra. The botanical affinity is unknown.

Occurrence: The known range is from the middle of the Gosport Sand to the lower Forest Hill Sand and the lower Red Bluff Clay; "infrequent" in 10 or 11/56 counted samples. Also reported by Elsik (1968) from the Paleocene of Texas.

Genus FAVOISPORIS Krutzsch, 1959b

FAVOISPORIS CONVEXA
Frederiksen, n. sp.

Pl. 1, figs. 13-17

Description: Size 22-29 microns; mean 25 microns; holotype 29 microns. Outline tri-

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PLATE 1

All specimens magnified 800 X

Figures — Page

1-4. *Concavisporites stavensis* Frederiksen, n. sp. 69
(1) Holotype; slide 10558 A-1, 35.7 x 123.1.
(2-3) Paratype; slide 10558 A-1, 42.0 x 115.5.
(4) Paratype; a specimen with no internal network of grooves, but with the interior side of the exine roughened; slide 10657 A-1, 24.0 x 116.8.

5-10. *Lygodium? labratum* Frederiksen, n. sp. 69
(5-6) Holotype; slide 10656 A-2, 21.2 x 118.0.
(7-8) Paratype; slide 10556 A-1, 23.2 x 113.9.
(9-10) Paratype; slide 10863 A-2, 32.4 x 112.0.

11-12, 18. *Undulatisporites elsikii* Frederiksen, n. sp. 69
(11-12) Paratype; folds of the exine around the ends of the labra occur in some specimens, such as this one, but it is unusual for the labra to bifurcate at their ends; slide 10680 A-1, 29.6 x 120.0
(18) Holotype; slide 10529 A-1, 31.3 x 111.7.

13-17. *Favoisporis convexa* Frederiksen, n. sp. 70
(13-15) Paratype; slide 10864 A-3, 31.2 x 111.9.
(16-17) Holotype; slide 10650 A-2, 27.8 x 113.0.

19-21. *Lycopodium venustum* Frederiksen, n. sp. 72
(19) Paratype; slide 10620 A-1, 23.9 x 119.7.
(20-21) Holotype; slide 10620 A-1, 25.5 x 118.5.

Sources of specimens (for localities, see Table 1): Gosport Sand—figs. 1-3, 7-8, loc. 11; Yazoo Clay—figs. 11-12, loc. 1; figs. 9-10, 13-15, loc. 2; figs. 5-6, 16-17, loc. 4; North Twistwood Creek Clay Member—fig. 4, loc. 6; Forest Hill Sand—figs. 19-21, loc. 3; Red Bluff Clay—fig. 18, loc. 8.

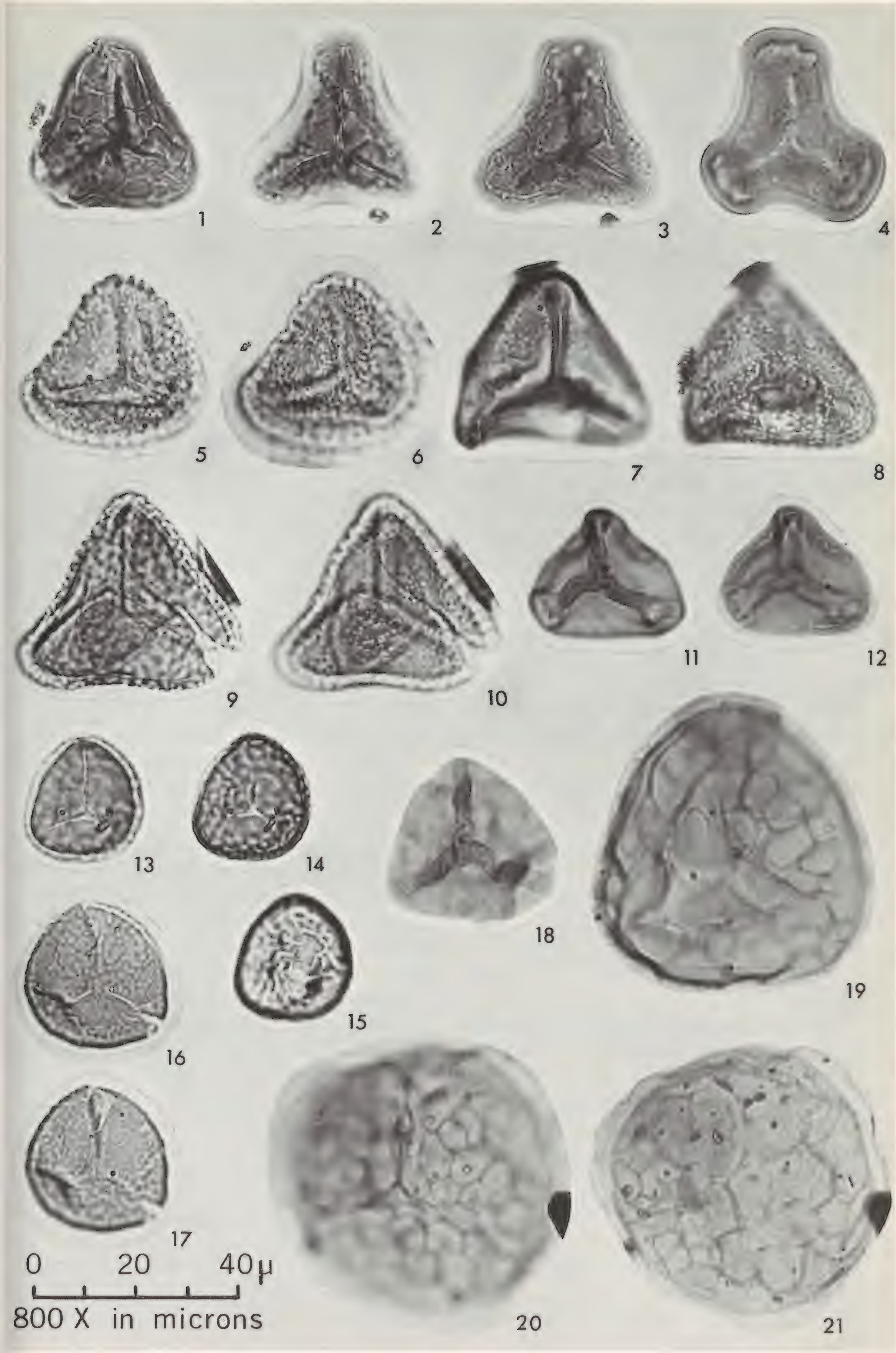
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PLATE 1

angular with slightly to strongly convex sides. Trilete, sutures slightly open, lips thin or lacking, rays extending 1/2-3/4 radius. Exine about 1 micron thick, with no thickening at the corners; nexine very thin; proximal face psilate; distal face verrucate to rugulate, the elements very low and 1-1.5 microns wide, with the negative reticulum mostly less than 0.5 micron wide.

Holotype: Pl. 1, figs. 16-17, slide 10650 A-2, 27.8 x 113.0, Yazoo Clay near Cynthia, Hinds County, Mississippi.

Remarks: The epithet *convexa* (Latin) refers to the convex sides of the spores. In the other species of *Favoisporis* the sides are straight to concave. In *Stereisporites semigranulus* Krutzsch, 1963b, and *S. semigranuloides* Krutzsch, 1963b, the exine is thicker at the corners than along the sides. The botanical affinity of *Favoisporis convexa* is unknown; the general shape and psilate proximal face suggest *Lycopodium,* but the verrucate ornamentation of the distal face does not.

Occurrence: The known range is from the base to the top of the Yazoo Clay; "infrequent" in five counted samples; only observed in samples from western Mississippi.

Genus LYCOPODIUM Linné, 1753

LYCOPODIUM VENUSTUM
Frederiksen, n. sp.

Pl. 1, figs. 19-21

Description: Size 45-78 microns including muri, mean 57 microns, holotype 57 microns. Outline round to rounded triangular. Trilete, sutures closed, straight to slightly wavy, extending 1/2 to full radius, labra rather inconspicuous, 0.5 micron wide. Exine 1 micron thick. Reticulum covers distal face and extends to rays or close to them on proximal face. Muri only about 0.3 micron wide, with a very small, triangular thickening at the intersections of the muri, muri baculate to somewhat conate in optical section, 1-4 microns high, somewhat higher at the corners of the grain in a few specimens. Lumina polygonal, 4-10 microns in diameter.

Holotype: Pl. 1, figs. 20-21, slide 10620 A-1, 25.5 x 118.5, Forest Hill Sand at Forest Hill, Hinds County, Mississippi.

Remarks: The epithet *venustum* (Latin, meaning "graceful") refers to the delicate muri in this species. *Retitriletes gracilimuris* (Krutzsch, 1959a) Krutzsch, 1963a, is smaller and has a large, free contact area; *R. reticuloides rhenanus* Krutzsch, 1963a, is slightly smaller and has a broken reticulum on the proximal face; *R. cyclogracilis* Krutzsch, 1963a, is smaller and has lower muri.

Occurrence: The known range is from the lower Yazoo Clay to the lower Forest Hill Sand and the lower Red Bluff Clay; "infrequent" in seven counted samples; not observed in samples from western Alabama.

Genus PROTEACIDITES Couper, 1953

PROTEACIDITES? LAXUS
Frederiksen, n. sp.

Pl. 2, figs. 1-4

Description: Size 21-38 microns (9 specimens), mean 29 microns, holotype 32 microns. Peroblate; outline triangular with slightly convex sides. Exine 2 microns thick, sexine:nexine apparently 1:1. Nexine psilate. Sexine appears to consist solely of a reticulum that is very loose on most specimens, separated from the nexine by as much as 4 microns; one specimen has a closely fitting reticulum (Pl. 2, fig. 3), and a few specimens lack the reticulum altogether (Pl. 2, fig. 4). Lumina of reticulum 2-4 microns in diameter; muri smooth to lumpy in design, coarsely beaded in optical section, 1-1.5 microns wide and 1 micron high. Triporate, pores 2-4 microns in diameter, cup-shaped in polar view.

Holotype: Pl. 2, figs. 1-2, slide 10637 A-2, 25.0 x 114.8, Yazoo Clay at Jackson, Mississippi.

Remarks: Proteacidites? laxus is characterized by its loose, coarse reticulum (*laxus*, Latin for "loose"). The botanical affinity is unknown. In shape and apertures these grains are similar to pollen of the Proteaceae, but the reticulum of *Proteacidites? laxus* is coarser than in that family. McLeroy (1971) stated that Late Cretaceous "proteaceous" pollen from the Northern Hemisphere was probably produced by the Symplocaceae, and, according to her abstract, she intends to publish a new genus to which *P.? laxus* might be assigned. The species is now assigned temporarily to *Proteacidites* for lack of a more suitable genus. There is also a considerable and interesting similarity between *Proteacidites? laxus* and triporate pollen grains of *Sclerosperma mannii* of the Palmae (illustrated by Sowunmi, 1972, pl. 3, fig. 8; pl. 4, fig. 1).

Occurrence: The known range is from the upper Cockfield Formation to the middle of the Red Bluff Clay; "infrequent" in 9/56 counted samples.

Genus MYRICA Linné, 1753

MYRICA PROPRIA
Frederiksen, n. sp.

Pl. 2, figs. 5, 9-11

Description: Size 21-29 microns, mean 24 microns, holotype 27 microns. Oblate; outline triangular with convex sides. Sexine 1 micron thick midway between pores, thickening gradually to about 2 microns at the pores (tumescence). Nexine everywhere very thin and indistinct. Sexine structureless or faintly tegillate; most of exine has a weakly granulate design, but the design is more sharply granulate over the atria where the underside of the sexine is roughened (tarsus pattern of Wodehouse, 1933, fig. 37). Entire outer surface of exine is smooth. Triporate, ektopores 0.5-1.5 microns in diameter; endopores about 5 microns in diameter; atria 2-2.5 microns deep and rather indistinct.

TABLE 4

Subspecies of *Triatriopollenites excelsus* (Potonié) Thomson and Pflug compared with *Myrica propria* Frederiksen, n. sp.

SUBSPECIFIC EPITHET	AUTHOR	CHARACTERS
excelsus	Potonié, 1931b	More sharply defined atria and less thickening of sexine at the pores
typicus	Pflug *in* Thomson and Pflug, 1953	Endoplicate
minor	*idem*	More nearly annulate than tumescent
turgidus	*idem*	More nearly annulate than tumescent
semiturgidus	*idem*	Psilate
microturgidus	*idem*	Smaller than *M. propria*

Holotype: Pl. 2, fig. 5, slide 10531 A-1, 27.2 x 127.3, Shubuta Clay Member of the Yazoo Clay near Hiwannee, Wayne County, Mississippi.

Remarks: Myrica propria differs from *Triatriopollenites excelsus* (Potonié, 1931b) Thomson and Pflug, 1953, as shown in Table 4. The epithet *propria* is Latin for "distinctive" and refers to the fact that this new species is easily recognized.

Occurrence: The known range is from the upper Cockfield Formation and the middle of the Gosport Sand to the lower Forest Hill Sand and the upper Red Bluff Clay; "infrequent" to "occasional" in 24/56 counted samples.

Genus TRIPOROPOLLENITES Pflug and Thomson *in* Thomson and Pflug, 1953

TRIPOROPOLLENITES DISCREPANS Frederiksen, n. sp.

Pl. 2, figs. 6-8

Description: Size 30-38 microns (5 specimens), holotype 30 microns. Oblate; outline triangular with slightly convex sides. Exine 2.5 microns thick; one thick, uneven fold usually parallels the outline. Sexine about 2 microns thick, structureless to faintly tegillate, surface smooth; nexine 0.5 micron or less thick, inner surface rough, producing sharply punctate design of exine. Triporate, ektopores 1-1.5 microns in diameter, with slight labra and no thickening of sexine at the pores. Nexine ragged near pores; obscure atria or slit-like vestibula may be present.

Holotype: Pl. 2, fig. 6, slide 10690 A-1, 24.3 x 113.6, North Twistwood Creek Clay Member of the Yazoo Clay at Barnett, Clarke County, Mississippi.

Remarks: Triporopollenites discrepans is characterized by its thick exine and slight labra, and by the contrast between the thick, smooth sexine and the thin, ragged, rough nexine to which the specific epithet refers (*discrepans,* Latin, "differing, being unlike"). The botanical affinity is unknown.

Occurrence: Observed only in the North Twistwood Creek Clay Member of the Yazoo Clay in eastern Mississippi and western Alabama; "infrequent" in two counted samples and also observed in one partially scanned sample.

Genus TRIVESTIBULOPOLLENITES Pflug *in* Thomson and Pflug, 1953

Betulaceoipollenites POTONIÉ, 1951, Palaeontographica, Abt. B, v. 91, p. 150, pl. 20, fig. 43.
Trivestibulopollenites PFLUG *in* THOMSON and PFLUG, 1953, Palaeontographica, Abt. B, v. 94, p. 84, pl. 9, figs. 25-41.
Betulaceoipollenites Potonié *ex* POTONIÉ, 1960, Beih. Geol. Jahrb., no. 39, p. 114, pl. 7, fig. 142.

Remarks: Betulaceoipollenites did not become valid in Potonié (1951b) because at that time Potonié did not give a generic description, nor did he indicate that this was to be a new genus. Potonié (1960, p. 115) pointed out that the type species of *Trivestibulopollenites* and *Betulaceoipollenites* are very similar to each other.

TRIVESTIBULOPOLLENITES ENGELHARDT Frederiksen, n. sp.

Pl. 2, figs. 12-14

Betulaceoipollenites cf. *B. bituitus* (Potonié, 1931a) Potonié, 1951b. ENGELHARDT, 1964, Mississippi Geol. Surv. Bull. 104, p. 76, pl. 4, fig. 42.
?*Betulaceoipollenites* sp. TSCHUDY and VAN LOENEN, 1970, U. S. Geol. Surv. Prof. Paper 643-E, pl. 3, fig. 8.

Description: Size 24-31 microns, mean 27 microns, holotype 30 microns. Oblate; outline rounded triangular. Exine 1 micron thick; sexine:nexine about 3:1. Many specimens have one or two coarse folds crossing the grain. Exine granulate; outline slightly uneven. Sexine slightly thickened at the

pores and abruptly arched, forming labra. Triporate, ektopores 2 microns in diameter. Vestibula 0.5-1 micron deep. Nexine ragged beneath vestibula; endopores 0.5-2.5 microns in diameter. Indistinct or partly formed columellae present across vestibula.

Holotype: Pl. 2, fig. 12, slide 10637 A-2, 40.1 x 113.4, Yazoo Clay at Jackson, Hinds County, Mississippi.

Remarks: Trivestibulopollenites betuloides Pflug *in* Thomson and Pflug, 1953, is psilate and has a thicker nexine. *Betulaceoipollenites bituitus* (Potonié, 1931a) Potonié, 1960, is psilate and has higher labra. The botanical affinity of *Trivestibulopollenites engelhardtii* is probably Betulaceae or Myricaceae.

Occurrence: The known range is from the upper Cockfield Formation and the middle of the Gosport Sand to the lower Forest Hill Sand; "infrequent" in 15/56 counted samples.

Genus PLICAPOLLIS Pflug, 1953

PLICAPOLLIS SPATIOSA Frederiksen, n. sp.

Pl. 2, figs. 15-18

Description: Size 22-29 microns (8 specimens), mean 25 microns, holotype 25 microns. Peroblate; outline triangular with nearly straight sides and blunt corners. Exine 1-1.5 microns thick; exine stratification obscure (sexine:nexine 1:1?); surface slightly rough, design weakly punctate to granulate; exine distinctly plicate. Triporate, ektopores 1-2 microns in diameter; nexine recurved at the pores, forming large, diamond-shaped to lenticular vestibula 2.5-3 microns deep; endopores 3-4 microns in diameter. Inner surface of sexine over vestibula is rough, so that design over vestibula is sharply granulate to punctate.

Holotype: Pl. 2, figs. 15-16, slide 10863 A-2, 38.7 x 118.0, Yazoo Clay, borehole AF-40, northern Hinds County, Mississippi.

Remarks: Plicapollis spatiosa is characterized by having straight sides and the large vestibula to which the specific epithet refers (*spatiosa,* Latin, "spacious"). The most similar species is *Triatriopollenites pseudoquietus* Krutzsch, 1960, which has shallow atria and convex sides. The botanical affinity of *Plicapollis spatiosa* is unknown.

Occurrence: The known range is from the lower Yazoo Clay to the lower Forest Hill Sand; "infrequent" in six counted samples; only observed in samples from western Mississippi.

Genus ECHIPERIPORITES van der Hammen and Wymstra, 1964 *emend.* Frederiksen

ECHIPERIPORITES TSCHUDYI Frederiksen, n. sp.

Pl. 2, figs. 19-22

?Aff. *Nothofagus* sp. TSCHUDY and VAN LOENEN, 1970, U.S. Geol. Surv. Prof. Paper 643-E, pl. 3, figs. 23, 27-28.

Description: Size 28-39 microns, mean 33 microns, holotype 35 microns. Originally spheroidal; outline round. Exine 1.5 microns thick, sexine:nexine 4:1; tegillate; ectosexine and endosexine equally thick. Sexine granulate and conate, the coni about 1 micron in diameter at the base, tapering evenly toward the point, and 1-2 microns high. Pores arranged only around the equator, although this is not immediately obvious because the grains were spheroidal and became compressed in many different orientations. Pores may be somewhat difficult to see; the grains are apparently 3- to 8-porate; holotype has 6 or 7 pores. Pores 1-2 microns in diameter; slight labra and (or) slight annuli present; vestibula 1-1.5 microns deep; nexine thickened (to about 0.5 micron) under vestibula; no endopores evident.

Holotype: Pl. 2, figs. 19-20, slide 10545 A-1, 34.3 x 113.2, North Twistwood Creek Clay Member of the Yazoo Clay at Little Stave Creek, Clarke County, Alabama.

PLATE 2

All specimens magnified 800 X

Figures — Page

1-4. *Proteacidites? laxus* Frederiksen, n. sp. 72
(1-2) Holotype; slide 10637 A-2, 25.0 x 114.8.
(3) Paratype; a specimen with a tightly fitting reticulum; slide 14963 C-1, 43.3 x 117.0. (4) Paratype, a specimen which has lost the reticulum; slide 10643 A-2, 40.9 x 113.2.

5, 9-11. *Myrica propria* Frederiksen, n. sp. 73
(5) Holotype; slide 10531 A-1, 27.2 x 127.3.
(9-10) Paratype; slide 10627 A-2, 19.1 x 112.7. (11) Paratype; slide 10529 A-1, 19.6 x 110.0.

6-8. *Triporopollenites discrepans* Frederiksen, n. sp. 74
(6) Holotype; slide 10690 A-1, 24.3 x 113.6.
(7-8) Paratype; slide 10547 A-2, 34.3 x 119.1.

12-14. *Trivestibulopollenites engelhardtii* Frederiksen, n. sp. 74
(12) Holotype; slide 10637 A-2, 40.1 x 113.4.
(13) Paratype; slide 10663 A-1, 17.4 x 125.1.
(14) Paratype; slide 10557 A-2, 24.4 x 112.7.

15-18. *Plicapollis spatiosa* Frederiksen, n. sp. 75
(15-16) Holotype; slide 10863 A-2, 38.7 x 118.0.
(17-18) Paratype; slide 10650 A-2, 21.5 x 119.8.

19-22. *Echiperiporites tschudyi* Frederiksen, n. sp.
(19-20) Holotype; slide 10545 A-1, 34.3 x 113.2.
(21-22) Paratype, a specimen lying in good proximal-distal orientation, that is, in polar view; slide 10558 A-1, 44.4 x 113.2.

23, 28-29, 34-35. *Monosulcites asymmetricus* Frederiksen, n. sp. 75
(23) Paratype; slide 10558 A-1, 34.0 x 120.4.
(28-29) Holotype; slide 10558 A-1, 43.4 x 120.5.
(34-35) Paratype; slide 10557 A-2, 19.9 x 113.3.

24-27. *Parsonsidites conspicuus* Frederiksen, n. sp. 78
(24-25) Holotype; slide 10627 A-2, 20.9 x 120.9.
(26-27) Paratype; slide 10627 A-2, 17.3 x 124.0.

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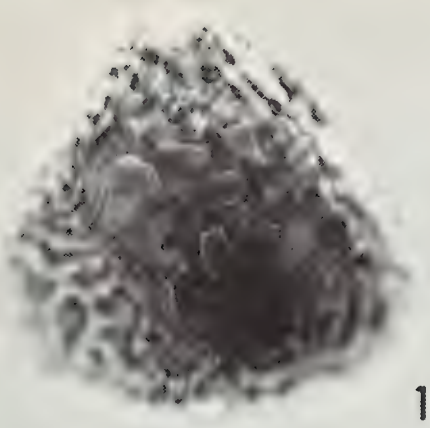

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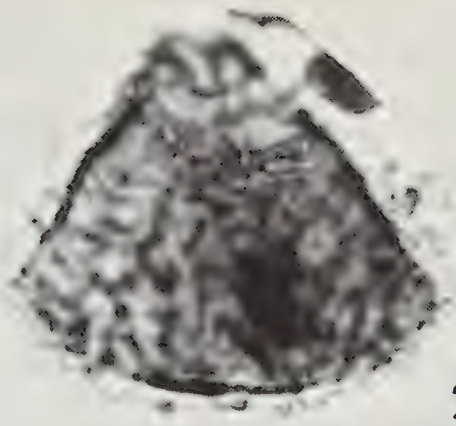

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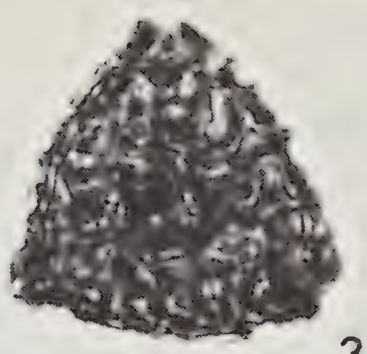

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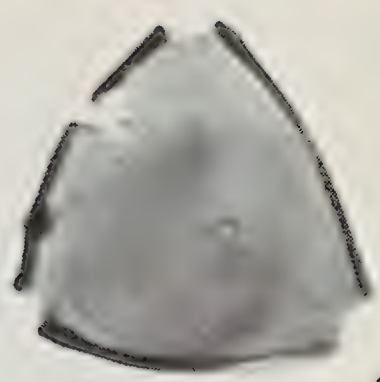

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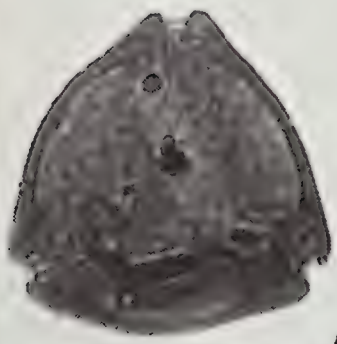

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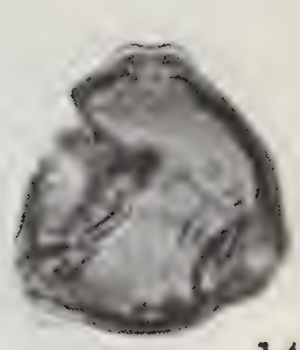

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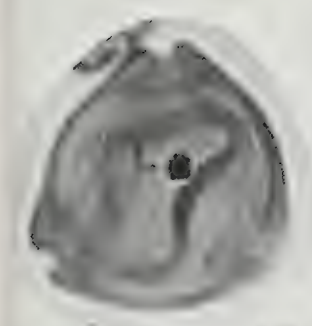

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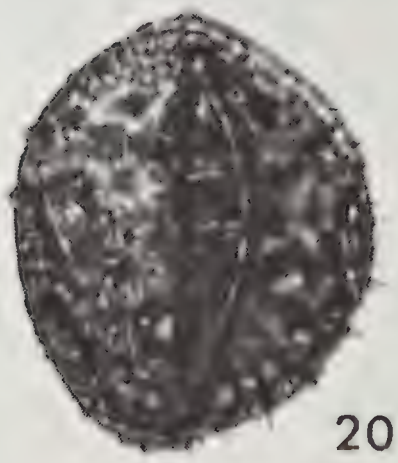

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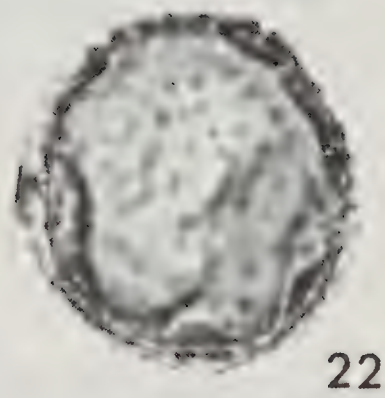

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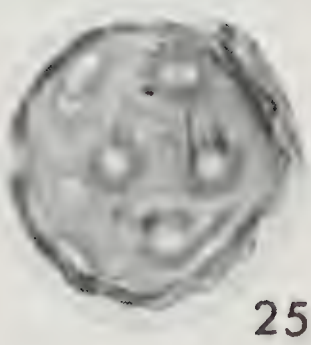

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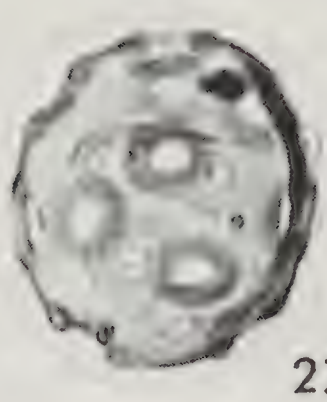

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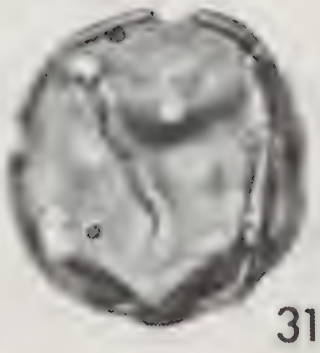

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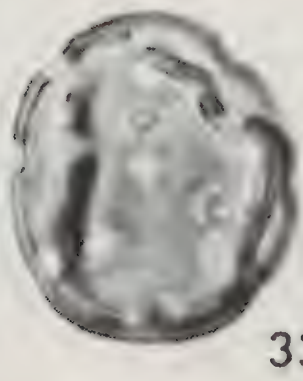

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PLATE 2

30-33. *Juglanspollenites infrabaculatus* Frederiksen, n. sp. 78
(30-31) Holotype; slide 10558 A-1, 26.9 x 121.1.
(32-33) Paratype; slide 10864 A-2, 24.0 x 125.2.

Sources of specimens (for localities, see Table 1): Gosport Sand–figs. 14, 21-23, 28-31, 34-35, loc. 11; Moodys Branch Fm.–fig. 4, loc. 5; fig. 13, loc. 6; Yazoo Clay–figs. 15-16, 32-33, loc. 2; figs. 17-18, loc. 4; figs. 1-2, 12, loc. 5; North Twistwood Creek Clay Member–fig. 6, loc. 7; figs. 7-8, 19-20, loc. 11; Shubuta Clay Member–fig. 5, loc. 8; fig. 3, loc. 11; Forest Hill Sand–figs. 9-10, 24-27, loc. 3; Red Bluff Clay–fig. 11, loc. 8.

Remarks: Echiperiporites akanthos van der Hammen and Wymstra, 1964, is periporate but otherwise seems to be similar to *E. tschudyi.* The genus *Echiperiporites* is herewith emended to include stephanoporate grains, as there appears to be no good reason why separate genera should be maintained for the two aperture types. *Malvacearumpollis bakonyensis* Nagy, 1962, has much larger grains than described species of *Echiperiporites,* and the grains have massive, rounded spines. The botanical affinity of *Echiperiporites tschudyi* is probably Malvaceae; the ornamentation is that of a typical malvaceous grain, and a number of modern species of the family have a vestibulate aperture structure.

Occurrence: The known range is from the lower Gosport Sand to the upper Red Bluff Clay; "infrequent" in 10/56 counted samples.

Genus PARSONSIDITES Couper, 1960

PARSONSIDITES CONSPICUUS Frederiksen, n. sp.

Pl. 2, figs. 24-27

Multiporopollenites sp. TSCHUDY and VAN LOENEN, 1970, U.S. Geol. Surv. Prof. Paper 643-E, pl. 3, figs. 31-32.

Description: Size 18-28 microns, mean 23 microns, holotype 24 microns. Outline round. Exine 1 micron thick; tegillate; ectosexine and nexine each slightly thinner than endosexine; infrapunctate, often indistinctly so. About 15-20 foramina distributed over the entire exine, 2-2.5 microns in diameter; annuli present, 5-7 microns in diameter; exine at the annuli 1.5 microns thick, increase in exine thickness due to thickening of endosexine, design of the annuli distinctly punctate to granulate; no atria present.

Holotype: Pl. 2, figs. 24-25, slide 10627 A-2, 20.9 x 120.9, Forest Hill Sand at Forest Hill, Hinds County, Mississippi.

Remarks: Parsonsidites conspicuus is characterized by the large, distinct, infrapunctate annuli to which the specific epithet refers. *Multiporopollenites maculosus* (Potonié, 1931c) Thomson and Pflug, 1953, is larger but has smaller foramina and annuli. *Parsonsidites psilatus* Couper, 1960, is larger, and its annuli do not have such a distinct design. The botanical affinity is probably Chenopodiaceae.

Occurrence: The known range is from the lower Moodys Branch Formation to the lower Forest Hill Sand and the upper Red Bluff Clay; "infrequent" in 22 or 23/56 counted samples.

Genus JUGLANSPOLLENITES Raatz, 1937

JUGLANSPOLLENITES INFRABACULATUS Frederiksen, n. sp.

Pl. 2, figs. 30-33

Description: Size 21-33 microns, mean 27 microns, holotype 27 microns. Outline round to slightly polygonal. Exine about 1.5 microns thick; distinctly tegillate; ecto-

sexine, endosexine and nexine each about 0.5 micron thick; design distinctly granulate; surface smooth. Exine usually crossed by several folds. About 15-20 foramina distributed over the whole exine; foramina round to oval, 1.5-2.5 microns in diameter; no labra, annuli or atria present.

Holotype: Pl. 2, figs. 30-31, slide 10558 A-1, 26.9 x 121.1, Gosport Sand at Little Stave Creek, Clarke County, Alabama.

Remarks: Juglanspollenites infrabaculatus is characterized by its lack of aperture structure and by its distinct infrabaculate (tegillate) sexine structure and granulate design. This combination of characters is not typical of either the Juglandaceae or the Chenopodiaceae.

Occurrence: The known range is from the lower Gosport Sand to the lower Forest Hill Sand and the lower Red Bluff Clay; "infrequent" to "occasional" in 28/56 counted samples.

Genus MONOSULCITES Couper, 1953 *emend.* Potonié, 1958

Monosulcites COUPER, 1953, New Zealand Geol. Surv. Paleont. Bull. 22, p. 65, pl. 8, figs. 130-133.

Monosulcites Couper *emend.* POTONIÉ, 1958, Beih. Geol. Jahrb., no. 31, p. 95, pl. 11, fig. 133.

Navisulcites ANDERSON, 1960, New Mexico Bur. Mines Min. Res., Mem. 6, p. 27, pl. 3, fig. 5.

Remarks: The sulcus in palm-like grains varies from gaping to closed to overlapping within one species. This variation occurs in the type species of *Monosulcites, M. minimus* (Cookson, 1947) Couper, 1953. *Navisulcites* was defined by Anderson (1960) as differing from other genera because the grains had gaping sulci, but this does not appear to be a character upon which a genus or perhaps even a species can be distinguished. In addition, the holotype of *Monosulcites minimus* itself has a gaping sulcus.

MONOSULCITES ASYMMETRICUS Frederiksen, n. sp.

Pl. 2, figs. 23, 28-29, 34-35

Description: Size 10-32 microns, mean 22 microns, holotype 23 microns. Outline of the typical grain is asymmetrically oval, with the widest part closer to one end than the other, like many palm grains; a few grains are elliptical or lenticular; ends usually pointed; length/width 1.2-1.5. Exine about 0.7-1 micron thick, sexine:nexine 2:1; psilate or rarely faintly infrapunctate. Sulcus extends nearly full length of grain; sulcus apparently with marginal thickenings about 0.5 micron wide, although these may only be the upturned edges of the sulcus. Sulcus typically slightly open; may be gaping or overlapping.

Holotype: Pl. 2, figs. 28-29, slide 10558 A-1, 43.4 x 120.5, Gosport Sand at Little Stave Creek, Clarke County, Alabama.

Remarks: Monosulcites minimus (Cookson, 1947) Couper, 1953, has a thicker exine; *Monocolpopollenites zievelensis* Pflug *in* Thomson and Pflug, 1953, is typically lenticular in outline. The botanical affinity is probably Palmae, although the grains of other monocotyledons are also similar, *e.g.*, *Libertia grandiflora* Sweet (Iridaceae) illustrated by Cranwell (1953, pl. 6, fig. 14).

Occurrence: The known range is from the upper Cockfield Formation and the lower Gosport Sand to the lower Forest Hill Sand and the lower Red Bluff Clay; "infrequent" to "occasional" in 32/56 counted samples.

Genus CONFERTISULCITES Anderson, 1960

CONFERTISULCITES FUSIFORMIS Frederiksen, n. sp.

Pl. 3, figs. 6-8

Monosulcites sp. TSCHUDY and VAN LOENEN, 1970, U.S. Geol. Surv. Prof. Paper 643-E, pl. 1, fig. 9.

Description: Size 35-97 microns (mostly 45-85 microns), mean 63 microns, holotype 68 microns. Outline elongate-lenticular with pointed ends; length/width 3-5.5. Exine 1 micron thick; sexine:nexine 3:1; psilate. Sulcus extends full length of grain; it is

slightly open or the edges are slightly overlapping along the whole length.

Holotype: Pl. 3, fig. 6, slide 10650 A-2, 27.1 x 123.0, Yazoo Clay near Cynthia, Hinds County, Mississippi.

Remarks: Confertisulcites fusiformis is characterized by its spindle-shaped outline (*fusiformis,* Latin, "spindle-shaped"). *Confertisulcites knowltonii* Anderson, 1960, and *Magnolia scotica* Simpson, 1961, are elliptical, with rounded ends; *Monocolpopollenites magnus* Kedves, 1961, is relatively broader and is psilate, chagrenate or infragranulate, that is, it looks more like modern *Magnolia* pollen than *Confertisulcites fusiformis* does. *C. fusiformis* may belong to the Magnoliaceae, however.

Occurrence: The known range is from the upper Cockfield Formation and the upper Gosport Sand to the top of the Yazoo Clay; possibly occurs also in the lower Forest Hill Sand; "infrequent" in 11 or 12/56 counted samples.

Genus LILIACIDITES Couper, 1953

LILIACIDITES VITTATUS
Frederiksen, n. sp.

Pl. 3, figs. 1-5

Liliacidites sp. TSCHUDY and VAN LOENEN, 1970, U.S. Geol. Surv. Prof. Paper 643-E, pl. 1, figs. 17-18.

Description: Size 28-38 microns, mean 34 microns, holotype 35 microns. Broadly lenticular in outline, the ends slightly pointed; length/width 1.1-1.5. Reticulate; muri in optical section ribbon-like, discontinuous and clavate, with the clavae 0.5-3 micron apart; between clavae, muri are supported by thin bacula. Exine including reticulum 2 microns thick; exine proper 0.5-0.7 micron thick, baculate interval 0.3-0.5 micron high, muri 0.7-1 micron high. Muri 1 micron wide and duplibaculate in design (Tschudy and van Loenen, 1970, pl. 1, fig. 18); lumina polygonal, about 2-3 microns in diameter on proximal face, 10-12 lumina present down length of grain; lumina may be smaller near sulcus. Sulcus extends full length or nearly full length of grain; usually slightly open, without thickened margins.

Holotype: Pl. 3, figs. 1-2, slide 10627 A-1, 17.7 x 109.6, Forest Hill Sand at Forest Hill, Hinds County, Mississippi.

Remarks: Monocolpopollenites papillosus Thomson and Pflug, 1953, has smaller lumina (more lumina present down length of grain). The epithet *vittatus* (Latin, "bound with a ribbon") refers to the ribbon-like appearance of the muri in optical section. The botanical affinity may be Palmae; however, of all species of monosulcate pollen grains observed in the Jackson Stage and adjacent strata, *Liliacidites vittatus* is the most likely to belong to *Myristica* (Myristicaceae), seeds of which were reported by Berry (1924) from upper Eocene or Oligocene strata of Texas.

Occurrence: The known range is from the middle of the Gosport Sand to the lower Forest Hill Sand and the upper Red Bluff Clay; "infrequent" to "occasional" in 22/56 counted samples.

LILIACIDITES TRITUS
Frederiksen, n. sp.

Pl. 3, figs. 13-16

Monosulcites sp. TSCHUDY and VAN LOENEN, 1970, U.S. Geol. Surv. Prof. Paper 643-E, pl. 1, figs. 10, 14.

Description: Size 32-39 microns, mean 34 microns, holotype 33 microns. Outline more or less oval; may be slightly polygonal or asymmetrical; ends rounded to slightly pointed; length/width 1.3-1.9. Exine about 0.3 micron thick excluding ornamentation; distinctly reticulate, the muri clavate in optical section and simpli- to duplibaculate in design. Muri 1 micron high and 0.7-1 micron wide; lumina round to polygonal to oval, 0.5 x 0.5 micron-0.5 x 1 micron in size on proximal side; lumina may be slightly smaller on distal side near sulcus. Sulcus extends full length or nearly full length of grain; sulcus gaping, slightly open all along

its length, or edges overlapping; edges of sulcus turned up so that the edges look thickened.

Holotype: Pl. 3, figs. 13-14, slide 10558 A-1, 34.6 x 115.3, Gosport Sand at Little Stave Creek, Clarke County, Alabama.

Remarks: Liliacidites variegatus Couper, 1953, has narrower muri; *Monocolpopollenites pflugii* Takahashi, 1961, has a shorter sulcus, and the muri are narrower and are baculate in optical section; *Monocolpopollenites areolatus retareolatus* Pflug *in* Thomson and Pflug, 1953, is indistinctly rugulate to reticulate. The epithet *tritus* means "familiar, commonplace" in Latin and refers to the large number of samples in which this species occurs. The botanical affinity is probably Palmae, but *Astelia trinervia* T. Kirk of the Liliaceae (illustrated by Cranwell, 1953, pl. 5, fig. 12) also look similar.

Occurrence: The known range is from the upper Cockfield Formation and the lower Gosport Sand to the lower Forest Hill Sand and the upper Red Bluff Clay; "infrequent" to "common" in 50/56 counted samples.

Genus CUPULIFEROIDAEPOLLENITES Thomson *in* Potonié, *et al.*, 1950 *ex* Potonié, 1960

CUPULIFEROIDAEPOLLENITES CERTUS Frederiksen, n. sp.

Pl. 3, figs. 9-12

Tricolpopollenites sp. TSCHUDY and VAN LOENEN, U.S. Geol. Surv. Prof. Paper 643-E, pl. 4, ?fig. 1.

Description: Size 15-26 microns, mean 20 microns, holotype 18 microns. Prolate to subprolate. Tricolpate, colpi extending nearly full length of grain; edges of colpi slightly thickened; colpi with distinct geniculi, sides of colpi pinched together at the geniculi. Exine 0.7-1 micron thick, sexine:nexine 2:1, psilate to faintly punctate.

Holotype: Pl. 3, figs. 9-10, slide 10558 A-1, 36.2 x 115.2, Gosport Sand at Little Stave Creek, Clarke County, Alabama.

Remarks: Cupuliferoidaepollenites certus is characterized by its distinct geniculi (*certus,* Latin, "definite, certain," referring to the strongly expressed geniculi). *Pollenites nodus* Doktorowicz-Hrebnicka, 1960, is larger. *Tricolpopollenites liblarensis fallax* (Potonié, 1934) Thomson and Pflug, 1953, is smaller and less sharply geniculate. Potonié (1934, p. 70) used the name *Pollenites fallax distentus* for larger, more distinctly geniculate specimens like *C. certus,* but he did not illustrate a specimen of *P. fallax distentus,* and the taxon is therefore invalid. The botanical affinity of *C. certus* may be Leguminosae; similar modern pollen are found, *e.g.,* in *Priotropis cytisoides* Wight and Arm and in *Dorycnium suffruticosum* Villars. A few grains of *C. certus* may also represent *Laguncularia* (Combretaceae), although in the latter genus the grains are usually more spheroidal than in *C. certus.*

Occurrence: The known range is from the lower Gosport Sand to the upper Red Bluff Clay; "infrequent" to "occasional" in 19/56 counted samples.

Genus FOVEOTRICOLPITES Pierce, 1961

FOVEOTRICOLPITES PROLATUS Frederiksen, n. sp.

Pl. 3, figs. 17-22

Description: Size 22-30 microns, mean 25 microns, holotype 30 microns. Typically prolate, occasionally subprolate. Tricolpate, colpi extending nearly full length of grain, margins not thickened. Exine 1.5 microns thick; tegillate; ectosexine, endosexine and nexine each about 0.5 micron thick; foveolae about 0.3 micron in diameter; ectosexine lumpy in optical section.

Holotype: Pl. 3, figs. 20-22, slide 10663 A-1, 16.2 x 122.1, Moodys Branch Formation near Rose Hill, Jasper County, Mississippi.

Remarks: Foveotricolpites sphaeroides Pierce, 1961, is subprolate and has thickened colpi margins. The botanical affinity of *F. prolatus* is unknown.

PLATE 3

All specimens magnified 800 X

Figures — Page

1-5. *Liliacidites vittatus* Frederiksen, n. sp. 80
(1-2) Holotype; slide 10627 A-1, 17.7 x 109.6.
(3-5) Paratype; slide 10556 A-1, 25.5 x 122.9.

6-8. *Confertisulcites fusiformis* Frederiksen, n. sp. 79
(6) Holotype; slide 10650 A-2, 27.1 x 123.0.
(7) Paratype; slide 10556 A-1, 25.3 x 123.1.
(8) Paratype; slide 10659 A-2, 19.5 x 114.5.

9-12. *Cupuliferoidaepollenites certus* Frederiksen, n. sp. 81
(9-10) Holotype; slide 10558 A-1, 36.2 x 115.2.
(11-12) Paratype; slide 10553 A-1, 39.6 x 114.1.

13-16. *Liliacidites tritus* Frederiksen, n. sp. 80
(13-14) Holotype; slide 10558 A-1, 34.6 x 115.3.
(15-16) Paratype; slide 10661 A-2, 22.1 x 109.3.

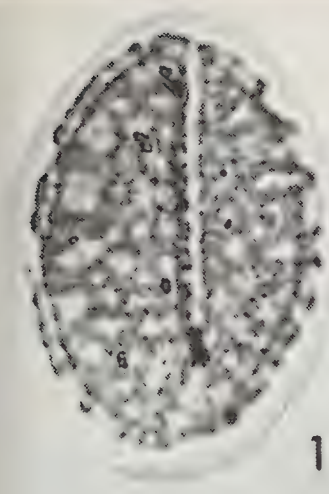
17-22. *Foveotricolpites prolatus* Frederiksen, n. sp. 81
(17-18) Paratype; slide 10663 A-1, 16.4 x 124.9.
(19) Paratype; slide 10558 A-1, 34.8 x 118.0.
(20-22) Holotype; slide 10663 A-1, 16.2 x 122.1.

23-27. *Fraxinoipollenites medius* Frederiksen, n. sp. 84
(23-24) Holotype; slide 10663 A-1, 16.9 x 118.7.
(25-27) Paratype; slide 10556 A-1, 34.4 x 112.2.

28-29. *Cupuliferoipollenites brevisulcatus* Frederiksen, n. sp. 85
(28) Holotype; slide 10645 A-2, 29.6 x 115.0.
(29) Paratype; slide 10645 A-2, 29.4 x 115.0.

30-34. *Albertipollenites? araneosus* Frederiksen, n. sp. 84
(30-31) Holotype; slide 10656 A-1, 31.9 x 108.9.
(32-33) Paratype; slide 10653 A-1, 28.9 x 113.8.
(34) Paratype, a specimen with ragged colpus floors, appearing tricolporate; slide 10637 A-1, 31.9 x 122.4.

Sources of specimens (for localities, see Table 1): Gosport Sand–figs. 3-5, 7, 9-10, 13-14, 19, 25-27, loc. 11; Cockfield Fm.–Moodys Branch Fm. contact zone–figs. 28-29, loc. 5; Moodys Branch Fm.–figs. 17-18, 20-24, loc. 6; figs. 11-12, loc. 11; Yazoo Clay–figs. 6, 30-33, loc. 4; fig. 34, loc. 5; North Twistwood Creek Clay Member–figs. 8, 15-16, loc. 6; Forest Hill Sand–figs. 1-2, loc. 3.



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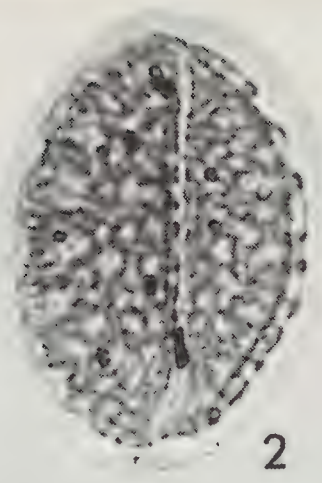

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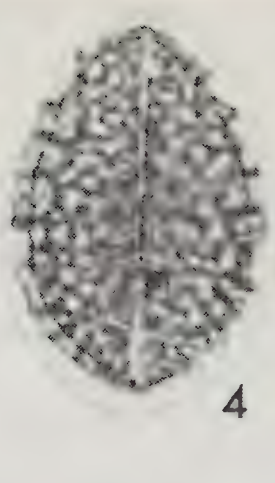

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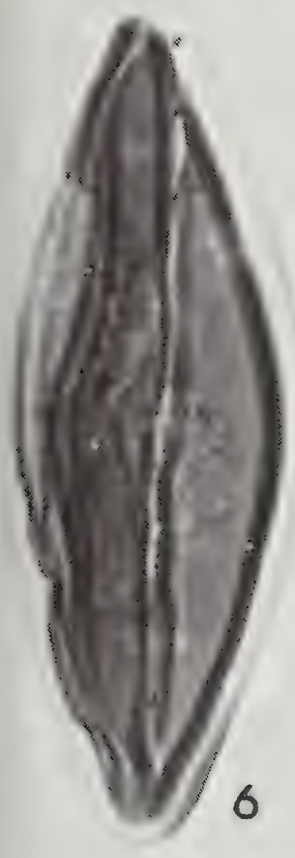

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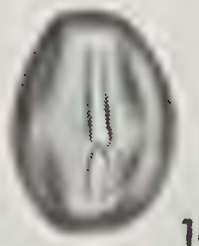

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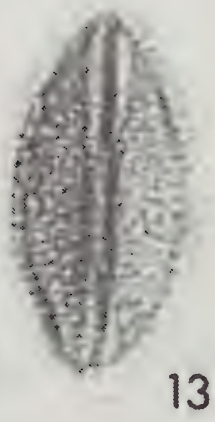

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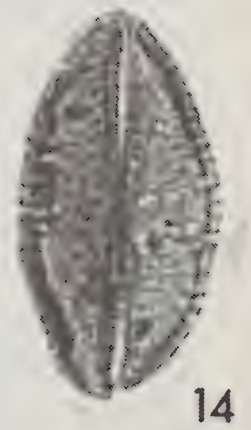

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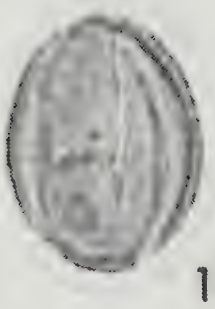

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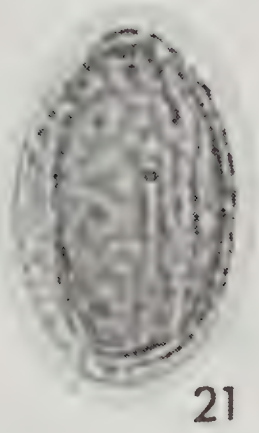

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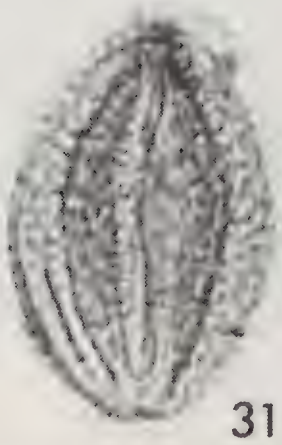
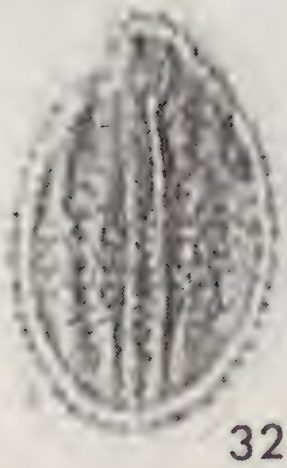
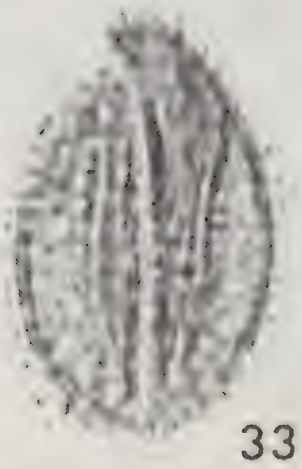


31



32



33

34

PLATE 3

Occurrence: The known range is from the upper Cockfield Formation and the lower Gosport Sand to the upper Red Bluff Clay; "infrequent" in 17/56 counted samples.

Genus FRAXINOIPOLLENITES Potonié, 1951a *ex* Potonié, 1960

FRAXINOIPOLLENITES MEDIUS
Frederiksen, n. sp.

Pl. 3, figs. 23-27

Description: Size 30-44 microns, mean 36 microns, holotype 35 microns. Prolate or occasionally perprolate (length/width 1.7-2.2); outline elongate oval with flattened ends. Tricolpate, colpi extending nearly full length of grain; margins may be slightly thickened. Exine 1-1.3 microns thick including ornamentation, exine proper about 0.3 micron thick. Finely reticulate; muri in optical section finely clavate, clavae 0.7-1 micron high, muri 0.3-0.5 micron high; lumina 0.3-0.5 micron in diameter.

Holotype: Pl. 3, figs. 23-24, slide 10663 A-1, 16.9 x 118.7, Moodys Branch Formation near Rose Hill, Jasper County, Mississippi.

Remarks: Fraxinoipollenites pudicus (Potonié, 1934) Potonié, 1960, is larger; *Tricolpopollenites haraldii* Manum, 1962, is smaller; *Menispermum scoticum* Simpson, 1961, has a smaller length/width (about 1.5). The specific epithet (*medius,* Latin for "middle") refers to the medium size of the grains in the species. The botanical affinity is unknown; the grains are larger and more prolate than in typical *Fraxinus.*

Occurrence: The known range is from the upper Gosport Sand to the lower Forest Hill Sand and the upper Red Bluff Clay; "infrequent" to "occasional" in 20/56 counted samples.

Genus ALBERTIPOLLENITES Srivastava, 1969

ALBERTIPOLLENITES? ARANEOSUS
Frederiksen, n. sp.

Pl. 3, figs. 30-34

Description: Size 21-37 microns, mean 29 microns, holotype 33 microns. Prolate; outline oval, poles broadly to narrowly rounded. Tricolpate, colpi extending nearly full length of grain, ends of colpi typically broadly rounded (Pl. 3, fig. 31), colpi margins slightly thickened. Bases of colpi sometimes torn or ragged—some specimens appear to be raggedly tricolporate (Pl. 3, fig. 34). Exine excluding ornamentation 1 micron thick; sexine:nexine 3:1. Reticulate, the muri clavate in optical section, clavae 0.7-1 micron high, muri 0.3 micron high; muri 0.3 micron wide, lumina 1.5-2.5 microns in diameter.

Holotype: Pl. 3, figs. 30-31, slide 10656 A-1, 31.9 x 108.9, Yazoo Clay near Cynthia, Hinds County, Mississippi.

Remarks: Albertipollenites? araneosus is characterized by its rather large lumina and narrow muri; the specific epithet (*araneosus,* Latin, "full of cobwebs") refers to the ornamentation. *Tricolpites bathyreticulatus* Stanley, 1965, is oblate; *Tricolpites geranioides* Couper, 1960, has wider muri and is larger. According to Srivastava's definition (1969, p. 54-55), *Albertipollenites* includes coarsely reticulate, tricolpate grains in which the reticulum does not become finer toward the colpi. The genus is also defined as containing "oblate to spheroidal" grains. To the writer's knowledge no genus has yet been proposed for prolate, coarsely reticulate, tricolpate grains like *Albertipollenites? araneosus.* However, at present the new species is tentatively assigned to *Albertipollenites* rather than to a new genus. The botanical affinity of *A.? araneosus* is unknown.

Occurrence: The known range is from the upper Cockfield Formation to the lower Forest Hill Sand and the upper Red Bluff Clay; "infrequent" to "occasional" in 21/56 counted samples.

Genus CUPULIFEROIPOLLENITES
Potonié, 1951a *ex* Potonié, 1960

CUPULIFEROIPOLLENITES
BREVISULCATUS
Frederiksen, n. sp.

Pl. 3, figs. 28-29

Description: Size 14-21 microns, mean 17 microns, holotype 19 microns. Prolate; sides straight and poles broadly rounded. Tricolporate; colpi about 0.5 micron wide, extending only 1/2-3/5 length of grain, margins not thickened; ora lalongate, typically 1.5-2 x 4-4.5 microns. Exine 0.5-0.7 micron thick at poles and about 1 micron thick at equator; thickening produces darkened equatorial band 6-7 microns wide. Nexine everywhere very thin. Exine psilate.

Holotype: Pl. 3, fig. 28, slide 10645 A-2, 29.6 x 115.0, Cockfield Formation-Moodys Branch Formation contact zone at Jackson, Mississippi.

Remarks: Cupuliferoipollenites brevisulcatus is characterized by its short colpi and prominent, lalongate ora and by the equatorial thickening of the exine (*brevis,* Latin for "short;" *sulcatus,* Latin for "furrowed;" referring to the short colpi). The species may belong to the Umbelliferae.

Occurrence: The known range is from the upper Cockfield Formation to the top of the Yazoo Clay; "infrequent" to "occasional" in 14/56 counted samples.

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NOTES ON THE FAUNA OF THE CHIPOLA FORMATION – XIII
THE FAMILY LIMIDAE (MOLLUSCA:BIVALVIA)

HAROLD E. VOKES
TULANE UNIVERSITY

In 1898 Dall described *Lima (Lima) tampaensis* from the "Chipolan Oligocene, near Bartow, and on the shores of Hillsborough Bay, near Tampa, Florida" (1898, p. 766, pl. 35, fig. 18). Subsequently in the same work he failed to include the species in his faunal lists from the Tampa region but did, apparently inadvertently, list it (1903, p. 1578) as an element in the fauna of "The Chipola Beds" with the prefix "C," which was said to include species from the "Chipola River at Ten-Mile Creek, and upper bed at McClellan's farm." Schuchert and Dall (1905, p. 354) give the type locality for the species as being "Hillsborough Bay, near Tampa, Florida."

This erroneous record is the only prior indication of the occurrence of any limid species in the Chipola fauna. In fact, Gardner's report of "imperfect and . . . immature" individuals from the Oak Grove Sand, which she somewhat uncertainly identified (1926, p. 53) as *Lima (Mantellum) carolinensis* Dall, constitutes the only prior record of any species of the family Limidae within the fauna of the entire Alum Bluff Group.

The more than one hundred specimens here studied prove referrable to four species, assigned to three genera within the family. All come from localities stratigraphically higher in the type area of the Chipola Formation than were those available to Gardner. (Her localities "one mile below" and "one mile west of Bailey's Ferry," are equivalent to TU 457 and 546 respectively.)

Family LIMIDAE Rafinesque, 1815

Genus LIMA Bruguière, 1797

Lima BRUGUIÈRE, 1797, Encycl. Méth. (Tabl. Vers), Plates, v. 2, pl. 206 [six species figured, but not named].

Lima CUVIER, 1798 [1797], Tabl. Elem. Hist. Nat., p. 421 [monotype, *Lima alba* Cuvier, with *Ostrea lima* Linnaeus in synonymy; no reference to Encycl. Méth. pl. 206.]

Mantellum RÖDING, 1798, Mus. Boltenianum, p. 160 [includes 4 species; Gray, 1847, designated as type *Ostrea lima,* which appears in the synonymy of the fourth species *Mantellum lima*].

Lima LAMARCK, 1799, Mém. Soc. Hist. Nat. Paris, v. 1, p. 88 ["Ex. *Ostrea lima.* Lin."]; LAMARCK, 1801, Syst. Anim. s. Vert., p. 136 [*L. squamosa* proposed for pl. 206, fig. 4, of Encyc. Méth., with *Ostrea lima* Linnaeus in synonymy].

Limigenus RENIER, 1807, Tav. Class. Anim., tab. vii [invalid ICZN Opinion 427].

Limaria RAFINESQUE, 1815, Analyse Nat., p. 147 [*non*Link, 1807].

Glaucion OKEN, 1815, Lehrb. Naturg., v. 3, Register, p. vii [invalid ICZN Opinion 417].

Radula "Klein" MÖRCH, 1853, Cat. Conch. Yoldi, pt. 2, p. 56 [*non* Gray, 1842; type by tautonomy: *vulgaris* Link, with "*Radula* Ch. 7 f. 651," in synonymy.]

Austrolima IREDALE, 1929, Rec. Australian Mus., v. 17, p. 165 [type orig. design.: *A. nimbifer* Iredale].

Type species, by subsequent tautonomy (Lamarck, 1801): *Ostrea lima* Linnaeus, 1758 [+ *Lima squamosa* Lamarck, 1801]. Recent.

Shell equivalved, higher than long, the anterior side straight, impressed, making the shell somewhat subangulate anteriorly, only slightly gaping; hinge margin relatively short with well-defined auricles that are approximately of equal length when viewed from the inner side, but when viewed externally has the anterior ear appearing to be much smaller than the posterior due to the impressed anterior lunular margin; hinge edentulous or with weak denticles near the outer ends of the margin; ligamental pit subumbonal, triangular, with the ventral margin slightly projecting into the body cavity of the shell; ventral margin broadly and regularly rounded, posterior margin short, straight, not as deeply impressed as the anterior. Ornamentation on main areas of valve of relatively strong radial ribs bearing raised scale-like imbrications on their crests; the anterior submargin usually with rather weak, irregularly radial to oblique ribs; the strong ribs of the main valve surface may continue, somewhat reduced in strength on to the posterior auricle.

The above generalized description covers a type of bivalved mollusc that has a world-wide distribution in the warmer tropical and subtropical waters. Authors have disagreed as to whether the various geographic entities involved are to be considered as separate species or as "formae" of one cosmopolitan type, which should be denominated as *Lima lima* (Linnaeus). Further, there has been almost universal disagreement as to which of the geographic entities should be considered as representing the Linnaean species, *sensu stricto*. Linnaeus gave the habitat of his species (1758, p. 699, sp. 175, as *"Ostrea lima"*) as "in O. meridionali," which, as noted by Dodge (1952, p. 186) "is almost completely uninformative." The writer (1963, p. 76) has reviewed the conclusions of previous workers as to this factor. There seems to have been a general concept that the various forms involved were so similar as to preclude morphologic distinction of the Linnaean species. The one possibly significantly variable character mentioned in the original description is the number of radiating ribs—22. Available material, other than that of the western Atlantic form, is not sufficient to permit more than the suggestion that further investigation of this character might yield information leading to definitive conclusions. Table 1 summarizes our results.

The most thorough, modern study of the Recent species is represented by Lamy's "Revision des Limidae vivants du Muséum National d'Histoire Naturelle de Paris" (1930). In this work he recognized *Lima lima* s.s., with 20 to 25 strong ribs; a "Forme *Sowerbyi* Deshayes" with 18 or 19 ribs; a "Forme *zealandica* Sowerby," a "Forme *tetrica* Gould," a "Var. *paucicostata* Sowerby" with 9 to 12 ribs; but noting that Lischke had reported a specimen from Japan with 16 ribs and that A. H. Cooke had indicated the rib count as varying between 9 and 15; and a "Var. *multicostata* Sowerby" with 36 ribs. No rib counts were given for *zealandica* Sowerby or *tetrica* Gould; both are said by other writers to have 18 costae.

Examination of these rib count figures, plus those gleaned from the works of many other writers, reveals that when only this one factor is taken into account there are a number of well-marked limid "species-groups:" (1) a *paucicostata*-group with 9-15, possibly 16, costae; (2) a *persquamifer-sowerbyi-tetrica-zealandica*-group with 18-21 costae; (3) a *lima-bullifera-tropicalis*-group with 20-25 costae; and (4) a *multicostata-nimbifer*-group with 30-36 costae.

TABLE 1

Geographic area:	Number of ribs on main body of valve															Number of specimens
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	
Western Atlantic	—	—	—	—	—	—	1	11	22	17	8	7	5	3	1	75
Somali Coast	—	—	2	5	2	—	—	—	—	—	—	—	—	—	—	9
Philippines	—	3	2	—	—	—	—	—	—	—	—	—	—	—	—	5
Australia	3	1	—	—	—	—	—	—	—	—	—	—	—	—	—	4
Mediterranean Sea (Bay of Naples)	—	—	2	—	1	1	—	—	—	—	—	—	—	—	—	4

Notes—The specimens from the Somali Coast have the high, rounded tubercles of *L. bullifera* Deshayes; those from the Philippines have been identified as *L. sowerbyi* Deshayes, originally described as from the Red Sea. The Australian specimens represent the *L. persquamifer* of Iredale.

In the Tulane collections there are numerous specimens of *Lima* from western Atlantic localities ranging from Florida to Brazil. As shown in Table 1, this species does not fall into any of these "groups," essentially occupying the interval between *"lima-bullifera-tropicalis"* and the *"multicostata-nimbifer"* numerations. The only described species with which the writer is acquainted that have rib-counts in this interval are the Japanese forms: *L. zushiensis* Yokoyama with about 26 ribs and *L. fujitai* Oyama with 28. Both of these differ markedly from the West Atlantic form in other characteristics: *L. zushiensis* being larger, somewhat proportionately narrower, and having a distinctive reddish-brown coloration marked by darker concentric banding—our specimens are uniformally white in color; *L. fujitai* though of similar coloration, is smaller and broader, almost semicircular in outline.

Lima caribaea d'Orbigny (1842, pl. 28, figs. 17-19; 1845, p. 354) was described as having 32 to 33 costae and hence was included by Lamy in the synonymy of his "Var. *multicostata* Sowerby." The original illustration of *caribaea,* a drawing, appears to have 27 or 28 costae on the main body of the valve and it seems possible that the 32 to 33 mentioned in the original description include the radials on the anterior auricle. If this indeed be the case then the present species is to be referred to *L. caribaea.* Not having access to the types or to topotype specimens, it will for the present be referred to as *Lima (Lima)* cf. *caribaea* d'Orbigny.

LIMA (LIMA) cf. CARIBAEA d'Orbigny

Plate 1, figure 1

cf. *Lima caribaea* d'ORBIGNY, 1842, *in* de la Sagra, Hist. fisica, polit. y nat. de Isla de Cuba, Pt. 2, Hist. Nat., Tom. 5, Molluscos, Atlas, pl. 28, figs. 17-19; 1845, (text), p. 354. [French ed., 1853, Mollusques, p. 337.]

This name is here tentatively applied to the western Atlantic species noted in the above discussion. These are marked by the possession of 24 to 31 strong radial costae on the main surface of the valve. These costae are separated by interspaces that are only approximately two-thirds as wide and are ornamented by raised squamae that do not cross the interspace areas. The hinge-line is short, with a ligamental pit that is triangular and longer than high. There are two minute denticle-like teeth at the dorsal angles in most specimens, with the inner, more ventral one, usually the strongest. In the largest specimens the outer, more dorsal denticles tend to become weakened, almost lost. It is a relatively small form, the largest specimen in our collection is a left valve having a height of 42.5 mm, length 36.2 mm and a semi-diameter of 8.2 mm. In contrast a large specimen from the Philippines, identified as *L. sowerbyi* Deshayes, has a height of 98 mm, length 77.1 mm, and a semi-diameter of 18.8 mm.

In addition to the specimens from the western Atlantic there are also three from the Chipola Formation that agree in all details with those from the Recent fauna. Two are small and immature, but the third is almost as large as the largest Recent specimen, the measurements of which are given above. This third specimen, from TU locality 547, has 24 radial costae; the two smaller ones, both from TU 555, have 25 and 26 costae, respectively.

Lima (Lima) tampaensis Dall (1898, p. 766, pl. 35, fig. 18) which, as noted above, was apparently inadvertently reported as from the Chipola Formation, is the only described American fossil species that might be confused with the present form. The original illustration shows only the interior of the valve and hence is not too useful. Dall, however, in his description notes that there are 27 radial costae, which are narrow and smooth, and "separated by wider channelled interspaces."

Figured specimen: USNM 647013; height 41.4 mm, length (incomplete) 34 mm, semi-diameter (left valve) 8.5 mm; locality TU 547.

Genus CTENOIDES Mörch, 1853

Ctenoides MÖRCH, 1853, Cat. Conch. Yoldi, pt. 2, p. 56.
Divaricolima ROVERETO, 1898, Atti Soc. Liguistica, v. 9, pp. 153, 167 [type, orig. desig.: *Lima eximia* Giebel, 1864, Fauna von Lattorf., p. 78, pl. 4, fig. 17; Oligocene, Germany].

Type species, by subsequent designation (Stoliczka, 1871): *Ostrea scabra* Born, 1778. Recent, South Florida, Yucatan Peninsula, West Indies to northeastern Brazil.

Shell ovate, high in proportion to length, somewhat compressed, with well-developed, narrow and elongate byssal gape bordered by lip-like reflections of the valve margins; auricles well-differentiated, the anterior one slightly larger than the posterior; resilifer trigonal, usually wider than high; cardinal area narrow, marked by relatively strong lateral teeth at either end below the auricles. Sculpture of numerous rounded, radial riblets that increase by divarication more or less along the mid-length of the valve; surface of ribs bearing fine, relatively distant squamose scales.

CTENOIDES (CTENOIDES) FLORIDANA (Olsson and Harbison)

Plate 1, figures 3, 4

Lima tenera G. B. SOWERBY II, 1843, Thesaurus Conch., v. 1, pt. 3, p. 84, pl. 21, figs. 10, 11.
NOT *Lima tenera* TURTON, 1826, Zool. Jour., v. 2, p. 362, pl. 13, fig. 2 [= *L. hians* (Gmelin)].
Lima (Ctenoides) floridana OLSSON and HARBISON, 1953, Acad. Nat. Sci. Phila., Mon. 8, p. 59, pl. 8, fig. 4 [Caloosahatchee Fmtn., Florida].

Prior to the issuance of Opinion 184 of the International Commission on Zoological Nomenclature, in 1944, which ruled that the new specific names appearing in the "Neues Systematisches Conchylien-Cabinet" of Martini and Chemnitz were not nomenclatorially available, most authors referred the present species (sometimes cited as a variety of *Lima scabra* Born) to "*Lima tenera* Chemnitz" (1784, pp. 267, 354, pl. 68, fig. 653). Subsequent to that date it has been usually cited as of the "Thesaurus Conchyliorum . . ." of G. B. Sowerby II, following Dall (1898, p. 768), who early had rejected the Chemnitz work. Unfortunately, however, the combination *Lima tenera* had been used previously in binomial nomenclature by Turton for the European form now generally referred to *L. hians* (Gmelin) (1791, p. 3332) and the Sowerby name must be rejected as a primary homonym.

The next available name appears to be "*Lima (Ctenoides)*" *floridana* Olsson and Harbison, which was originally proposed for the Pliocene form referred to *tenera* by Dall (1898, p. 768), being described as: "Similar to *Lima tenera* in sculpture but differs by its narrower form, hence somewhat more convex or vaulted along its slightly inclined longitudinal axis; with a narrower, heavier and higher hinge area bearing a deeper ligamental pit. Hinge as in *tenera* . . ." Measurement of 25 right and 25 left valves of Pliocene specimens from the Caloosahatchee River area (TU 529) compared with those of a similar number of specimens from the coast of Panamá (TU R-109) reveals that the Pliocene and Recent forms are almost wholly identical in relative valve proportions, differing only in that the fossil specimens tend to be smaller than those from the Recent seas. This may, however, be an accident of preservation and collection, although it may also be significant since all of the lower Miocene specimens from the Chipola Formation tend to be, in turn, notably smaller than are those from the Pliocene strata, suggesting that we may have here another example of progressive phyletic size-increase. Table 2 indicates the relative size and proportions of the specimens measured.

It may be noted that the range of variation in the length to height ratios is slightly greater in the Recent than in the fossil specimens. Indeed, it is actually greater than indicated in the table for one obviously gerontic specimen from off the coast of Panamá (TU R-109), with a ratio of .556, being 30.6 mm long and 55.0 mm high, was not included in the above calculations. It may also be observed that the dimensions given for the type specimen of *Ct. floridana* –height 27 mm, length 20.8 mm, diameter 10.7 mm" yield a ratio of .770 and indicate a valve a little broader than the average of either the Recent or the fossil specimens.

TABLE 2

	Recent (TU R-109)	Pliocene (TU 529)	Miocene (TU 555)
number measured	50	50	9
average length	30.7 mm.	18.7 mm	7.3 mm
average height	40.6 mm.	24.7 mm	9.6 mm
length:height ratio	.756:1	.758:1	.754:1
length:height range	.596 – .845:1	.683 – .839:1	.634 – .873:1

Study of the ligamental area of these same specimens reveals that there is also a high degree of variability in the relative height of the area as well as in the size and depth of the resilial pit. In general, however, it may be observed that the more narrow specimens appear to have a relatively higher area than do those in which the longer shell allows a greater hinge-length; the highest (7.6 mm) and most strongly developed area is on the gerontic specimen cited above.

The collections from the Chipola Formation contain nine entire and twelve broken valves that are here assigned to *Ct. floridana.* All are from locality TU 555, near the uppermost strata of the formation as exposed in the banks of the Chipola River.

Figured specimens: Fig. 3, Hypotype, USNM 647014; height 21.3 mm. length 13.5 mm, semi-diameter (right valve) 3.9 mm; locality TU 555. Fig. 4, Hypotype, USNM 647015; height 12.2 mm, length 9.2 mm, semi-diameter (right valve) 2.4 mm; locality TU 555.

CTENOIDES (CTENOIDES) cf. SCABRA (Born)

Plate 1, figure 2

cf. *Ostrea scabra* BORN, 1780, Test. Mus. Caes. Vind., p. 110.

cf. *Ostrea glacialis* GMELIN, 1791, Syst. Nat., ed. 13, p. 3332 [pars, not var. β = *Ctenoides floridana*].

Three broken valves in the Chipola collections from locality TU 555 are distinguished from the forms here referred to *Ctenoides floridana* by the possession of stronger, more squamose, radial ribbing, an apparently broader valve area as compared with the height, and a tendency to show relatively strong concentric growth interruptions on the earliest portion of the shell. The first character is the feature that distinguishes the typical form of *Ct. scabra* from *Ct. floridana,* the two species being otherwise similar in shape and hinge structure. The available material is too scanty to permit any significant conclusions to be drawn from measurements of valve shape, and the growth "interruptions" may be only a function of type of preservation. Accordingly these specimens are here tentatively referred to *Cetnoides scabra* pending discovery of additional and more complete material for study.

Figured specimen: USNM 647016; height 13.2 mm, length (incomplete) 11.7 mm, semi-diameter (right valve) 2.8 mm; locality TU 555. [Length:height ratio .886+:1]

Genus LIMARIA Link, 1807

Limaria LINK, 1807, Beschr. Natur.-Samml. Univ. Rostock, p. 157.

Mantellum MÖRCH, 1853, Cat. Conch. Yoldi, pt. 2, p. 57 [*non Mantellum* Röding, 1798, = *Lima* Bruguière, 1797].

Promantellum IREDALE, 1939, Gt. Barrier Reef Exped., 1928-29, Sci. Rpts., v. 5, no. 6, Moll., Pt. 1, p. 385 [type, orig. desig.: *P. parafragile* Iredale].

Submantellum OLSSON and HARBISON, 1953, Acad. Nat. Sci. Phila., Mon. 8, p. 60 [type orig. desig.: *Lima orbignyi* Lamy].

Limatulella Sacco, STENZEL, KRAUSE and TWINING, 1957, Univ. Texas Publ. 5704, p. 86.
Winckworthia GLIBERT and VAN DE POEL, 1965, Mém. Inst. Roy. Sci. Nat. Belg., (Ser. 2) fasc. 78, p. 49 [type, orig. desig.: *Ostrea tuberculata* Olivi].

Type species, by subsequent designation (Winckworth, 1930): *Limaria inflata* Link, 1807 = *Ostrea tuberculata* Olivi. Miocene to Recent, Mediterranean Sea and western Europe.

Somewhat obliquely elliptical, moderately to rather strongly inflated shell that has a wide posterior gape immediately below the cardinal margin and a narrower anterior one that is well separated from that margin. The sculpture consists of irregularly spaced narrow radial riblets separated by wide interspaces; the number of riblets and their relative spacing tends to vary so greatly within a species that it is not a reliable character for identification, and the relative width of the interspaces may vary widely in different area of the same valve. The cardinal region is marked by relatively small auricles, subequal in size, the anterior being slightly longer than the posterior; the broad ligamental pit is essentially central but extends slightly more anteriorly than posteriorly. The hinge is edentulous.

There has been much uncertainty as to the use of *Limaria* Link, 1807. This stemmed to a considerable extent from Iredale's (1939, pp. 382, 286) disagreement with Winckworth's (1930, p. 116) designation of *inflata* Link as type species.

In proposing the genus Link included four species, of which the first was *vulgaris* Link, with "*O. Lima.* L. G. [melin] p. 3332" in the synonymy, and the fourth was *inflata* with sole reference to "Ch. Conch. 7. t. 68. f. 641. a." Iredale apparently misinterpreted the version of the International Rules of Zoological Nomenclature then in force when he stated (p. 386) that "the type of *Limaria* must be *vulgaris* by tautonomy . . ." It is true that the selection of *vulgaris* was strongly recommended by the Rules (Art. 30, Par. III, Recommendations *i*

PLATE 1

1. *Lima (Lima)* cf. *caribaea* d'Orbigny.
   Figured Specimen—USNM 647013, (X 1); height 41.4 mm, length 34 mm.
   Locality: TU 547.

2. *Ctenoides (Ctenoides)* cf. *scabra* (Born).
   Figured Specimen—USNM 647016, (X 4); height 13.2 mm, length 11.7 mm.
   Locality: TU 555.

3, 4. *Ctenoides (Ctenoides) floridana* (Olsson and Harbison).
   3. Hypotype. USNM 647014, (X 3); height 21.3 mm, length 13.5 mm.
      Locality: TU 555.
   4. Hypotype. USNM 647015, (X 4); height 12.2 mm, length 9.2 mm.
      Locality: TU 555.

5, 6, 7. *Limaria (Limaria) chipolana* H. E. Vokes, n. sp.
   5. Paratype. USNM 647018, (X 6); height 6.2 mm, length 4.9 mm.
      Locality: TU 459.
   6. Holotype. USNM 647017, (X 6); height 9.0 mm, length 7.6 mm.
      Locality: TU 459.
   7. Paratype. USNM 647019, (X 6); height 5.6 mm, length 4.9 mm.
      Locality: TU 459.

All specimens are from the Chipola Formation, lower Miocene, of Florida. Magnifications approximate only.

PLATE 1

and *m,* as published in the Proceedings of the Biological Society of Washington, v. 39, pp. 75-104, 1926), but the synonym *lima,* being only *virtually* tautonomous with *Limaria* did not fix the type solely on the basis of the original publication (Article 30, I, d). Type designation by virtual tautonomy was a matter for subsequent designation and the designating author was clearly given the right to select a species from the original list other than that indicated by the virtual tautonomy in cases where "such preference is strongly contraindicated by other factors." In the present case the "other factors" included the fact that the designation of *vulgaris* would make *Limaria* an absolute synonym of *Lima* Bruguière. The designation of *inflata* would make the name available for the group long known by authors under the name of *Mantellum* Bolten [= Röding], 1798, after Mörch and H. & A. Adams, who had overlooked the designation of *Ostrea lima* as type by Gray, 1847, making *Mantellum* also an absolute synonym of *Lima.*

Iredale is correct, however, in noting that *inflata* Link, being based upon the Chemnitz figure 649a, was not the same form as the *Ostrea inflata* of Gmelin (1791, p. 3321) the references for which include the Chemnitz figure 649b [= *bullata* Born], but not 649 a. Winkworth clearly missed this distinction when he synonymized the *inflata* of Link with that of Gmelin. It is possible that he was influenced by the fact that Lamarck (1819, p. 156) had used the name *inflata* for, among other references, Chemnitz's fig. 649a. According to the extensive synonymy of Bucquoy, Dautzenberg and Dollfus (1887, p. 53), the next available name for *inflata* Link (non Gmelin) is *Ostrea tuberculata* Olivi (1792, p. 120).

Stenzel, Krause and Twining (1957, pp. 86-88) appear to have been misled by Iredale and concluded that the next available name for the group previously known as *Mantellum* was *Limatulella* Sacco, 1898, type by original designation: *Lima loscombii* Sowerby, 1823. Typical forms of *Limatulella* differ from those of *Limaria,* however, in the almost complete absence of the anterior and posterior marginal gapes.

LIMARIA (LIMARIA) CHIPOLANA

H. E. Vokes, n. sp.

Plate 1, figures 5-7

This is the most abundant and widely distributed limid species in the Chipola collections, being represented by 116 specimens, many of which, however, are broken and incomplete. The majority of the specimens come from one locality, TU 459, which has yielded 86 valves; twelve are from TU 548, six from TU 825, and the rest are from seven different collection sites.

Limaria chipolana is a typical representative of the genus differing from most other described western Atlantic fossil and Recent species primarily in its smaller size, the largest of the valves in the collection being but 13.2 mm high, 10.6 mm long and 2.6 mm in diameter. This size difference is particularly marked with respect to the "middle" Miocene, Calvert Formation, species *L. papyria* (Conrad) (1841, p. 30; 1845, p. 76, pl. 43, fig. 7), the "upper" Miocene *L. carolinensis* (Dall) (1898, p. 767, pl. 35, fig. 21) of the Duplin Marl and related units, and the Pliocene *L. caloosana* (Dall) (1898, p. 767, pl. 28, fig. 3) of the Caloosahatchee Formation. It is also proportionately higher and narrower in general outline than is any of these three species, being most closely approximated in this aspect by *L. pellucida* (C. B. Adams) (1846, p. 102), which appears to be even more narrow with respect to height than *L. caloosana.* It may be distinguished from *L. pellucida* by the much more broadly and regularly rounded posterior and posteroventral margin, a feature that serves also to distinguish it from the other species mentioned above. Surface ornament is of the type characteristic of the genus, but the radial ribbing is absent over the greater part of the anterior slope of the valve resulting in a long, unusually broad smooth margin area. Posteriorly the ribbing dies out below the auricle and both auricles are smooth. This latter feature is shared with *L. pellucida* and some specimens *L. carolinensis,* but the majority of the valves of the latter species available for study showed at least traces of ribbing on the posterior auricle.

TABLE 3

	carolinensis	*caloosana*	*pellucida*	*chipolana*
number measured	14	50	7	26
average length	24.9 mm	22.7 mm	10.4 mm	5.1 mm
average height	27.2 mm	25.0 mm	13.5 mm	6.3 mm
average diameter	9.1 mm	7.3 mm	2.6 mm	1.5 mm
ratio length/height	.914:1	.908:1	.770:1	.801:1
range length/height	.850–1.00	.819–.977	.721–.813	.702–.857
ratio length/diameter	.365:1	.322:1	.250:1	.288
range length/diameter	.304–.428	.252–428	.226–.278	.245–.348

In overall appearance *L. chipolana* is most similar to *L. smithvillensis* (Stenzel and Twining) (1957, p. 88, pl. 8, fig. 13, as *"Lima (Limatulella)"*), both species being marked by a very regularly rounded posterior and postero-ventral margin. But the Texas Eocene species is proportionately much longer with a length/height ratio of .941, and this has led to the development of a more broadly rounded antero-ventral margin than is present in our lower Miocene form. In addition the posterior auricle of *L. smithvillensis* is described as being ornamented by "many crowded, fine, low ribs."

Table 3 compares *L. chipolana* with specimens from the type locality of the Jackson Bluff Formation* (Tu 60) and from the Caloosahatchee Formation (TU 529).

The Jackson Bluff species was identified by Mansfield (1932, p. 67, pl. 13, fig. 4) as "*Lima (Mantellum) carolinensis* Dall;" the Caloosahatchee specimens are here identified as *L. caloosana* (Dall). In addition measurements are given of the few available specimens of *L. pellucida* (C. B. Adams) from Pleistocene and Recent localities in Florida and the Caribbean Sea.

The writer is inclined to the opinion that the relative shell diameter (and inflation ratio) is not a significant specific character in this genus. Specimens of almost identical length and height may differ considerably in diameter, to the point that it seems quite possible that this may be an expression of sexual dimorphism. Two valves of *L. caloosana,* for example, each 25.3 mm in height, and differing in length only by 0.1 mm, have diameters of 7.2 and 8.4 mm, giving length/diameter ratios of .313 and .363 respectively. It is here assumed that the more inflated individuals reflect the larger gonads of the females.

Figured specimens: Fig. 6, Holotype, USNM 647017; height 9.0 mm, length 7.6 mm, semi-diameter (right valve) 1.9 mm; locality TU 459. Fig. 5, Paratype, USNM 647018, height 6.2 mm, length 4.9 mm, semi-diameter (left valve) 1.5 mm; locality TU 459. Fig. 7, Paratype, USNM 647019, height 5.6 mm, length 4.9 mm, semi-diameter (right valve) 1.4 mm; locality TU 459. Other occurrences: Tulane University localities 555, 818, 820, 821, 825, 826, 827, 1020.

*Akers (1972, Tulane Stud. Geol. Paleont., v. 9, pp. 18-24, 30-34, figs. 1, 2, 4) has recently demonstrated that the Jackson Bluff and Yorktown formations contain planktonic foraminiferal faunas equivalent to those of the upper part of the Neogene zone 18 and to zone 19 of Blow. These are considered as being of lower and lower middle Pliocene age.

LOCALITY DESCRIPTIONS

Note: All of the following Tulane University fossil localities are in the Chipola Formation of lower Miocene age, from Calhoun County Florida.

459. Steep bank on east side of Chipola River about 1500 feet above mouth of Taylor Lake Branch (NW¼ Sec. 29, T1N, R9W).
547. West bank of Chipola River about 2000 feet above mouth of Four Mile Creek (SW¼ Sec. 29, T1N, R9W).
548. West bank of Chipola River at sharp bend about 1800 feet below mouth of Farley Creek (NW¼ Sec 29, T1N, R9W).
555. East bank of Chipola River about 1000 feet above mouth of Four Mile Creek (SW¼ Sec. 29, T1N, R9W).
818. Farley Creek, south bank 0.1 mile west of bridge on Florida Highway 275 (SW¼ Sec. 21, T1N, R9W).
820. Farley Creek at bridge on Florida Highway 275 (SW¼ Sec. 21, T1N, R9W).
821. Farley Creek, 0.1 mile east of bridge on Florida Highway 275 (SW¼ Sec. 21, T1N, R9W).
825. Farley Creek, at abandoned mill about one-quarter mile west of bridge on Florida Highway 275 (SW¼ Sec. 21, T1N, R9W).
826. Farley Creek, about 0.1 mile west of TU 825 (on line between Secs. 20 and 21, T1N, R9W).
827. Farley Creek, about one-half mile west of bridge on Florida Highway 275 (SE¼ Sec. 20, T1N, R9W).
1020. East side Chipola River inside mouth of small, unmapped tributary about one-half mile below power line crossing (NE¼ Sec. 20, T1N, R9W).

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NOTES ON THE FAUNA OF THE CHIPOLA FORMATION – XIV

ON THE OCCURRENCE OF *BURSA* (MOLLUSCA:GASTROPODA), WITH COMMENTS ON THE GENUS

EMILY H. VOKES
TULANE UNIVERSITY

The gastropod genus *Bursa* Röding, 1798 (type species: *Murex bufonius* Gmelin) has a long history in the New World, with two forms being known from the Eocene Talara Formation and Oligocene Chira Formation of Peru (Olsson, 1930, pp. 62, 63). By Miocene time the group had spread into the Caribbean and from then on flourished, with numerous species known from both the fossil and Recent faunas. Hitherto there have been no fossil representatives of *Bursa* reported from the southern United States, but in this paper two species are recorded for the first time. A single specimen of a species originally described from the middle Miocene of Santo Domingo, *B. amphitrites* Maury, has been collected from the type area of the middle Miocene Shoal River Formation of northwestern Florida (see fig. 1). This form is widespread in the Caribbean Miocene; as was noted by Woodring (1959, p. 207) it is common in the Gatun Formation of Panamá (in the Tulane collections there are over 80 specimens from TU 757 and 958), and also occurs in the Punta Gavilán Formation of Venezuela, originally described as *B. albofasciata boussingaulti* Rutsch.

In the lower Miocene fauna of the Chipola Formation there have been found rare specimens of another species of *Bursa,* which thus becomes the oldest reported from the southern United States. Readers of previous papers in this series will not be greatly surprised to learn that it is identifiable as one named from the Aquitaine Basin of France by Cossmann and Peyrot (1923). This form was first figured by Grateloup in the Atlas to the *Conchyliologie Fossile du Bassin de l'Adour* as "*Ranella scrobiculata* Kiener," alias *Murex scrobilator* Linné, a Recent Mediterranean species, with which it does have some affinities. However, the differences are such that it was given a new name, *Apollon pelouatensis,* by Cossmann and Peyrot.

This Chipola and Aquitaine species is clearly akin to the *B. caelata* (Broderip) group. In this assemblage we would include in addition to the Recent East Pacific *B. caelata: B. calcipicta* Dall, also from the Recent East Pacific; *B. mexicana* Perrilliat Montoya, from the Pliocene Agueguexquite Formation of Mexico*, which is exceedingly close to *B. calcipicta* (the holotype of the latter is figured in Keen, 1971, fig. 965); *B. amphitrites* Maury; *B. thomae* (d'Orbigny) from the Recent Caribbean; and *B. corrugata* (Perry), named without locality but which may be the correct name for the Caribbean "analog" of *B. caelata.* There are others such as *B. ponderosa* (Reeve), which may be a synonym of *B. caelata,* and *B. pustulosa* (Reeve), a heavily noded form from the mid-Atlantic Ascencion Island, that belong here also. In all of this *"caelata"* group the ornamentation is much alike, and closely resembles that of *B. pelouatensis;* however, all differ in a single striking way from the older Chipola-Aquitaine species in that the varices of the latter are not aligned up the spire, whereas in all of the *"caelata"* group they are aligned in two rows on either side of the spire.

The systematics of the Bursidae have been particularly complicated by the fact that there is a degree of similarity between certain of the Cymatiidae and certain of the Bursidae. The similarity is much more apparent than real, and consists primarily of the corrugated nature of the aperture, both on the inner and outer lips, and the presence of varices. Typical bursids have two varices

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*This same species occurs in the Pleistocene Moín Formation, Puerto Limon, Costa Rica (TU 954).

arranged on either side of the shell, forming two neat rows up the spire. Typical cymatiids, on the other hand, have two varices per whorl, but they are off-set and consequently do not form a line up the spire. Unfortunately there are exceptions to both of these rules, for there are the members of the genus *Apollon* Montfort (type: *Murex gyrinus* Linné), a cymatiid in which the varices are arranged in perfect symmetry on opposite sides of the spire; and there are the members of the bursid subgenus *Tutufa* Jousseaume in which the varices are off-set. The primary distinguishing character between the Bursidae and the Cymatiidae, therefore, is the anal gutter that *always* occurs in the Bursidae and never in the Cymatiidae.

The problem of the "frog shells" *vs.* the "tritons" was covered by Dall (1904) in a review of the two groups and in general his observations agree with those of the writer. However there are certain differences in nomenclature for the accepted groups, the one of primary concern here being his usage of the name *Bufonaria* in place of *Tutufa.* Dall considered the type of *Bufonaria* Schumacher to be *Murex scrobilator* Linné (as *scrobiculator,* a change in spelling by Linné in the 12th Edition); however, the type had been previously designated as *Ranella spinosa* Lamarck, making *Bufonaria* a synonym of *Gyrinium* Link. *Murex scrobilator* was Schumacher's second species, under the name *Bufonaria pesleonis,* and was subsequently named type of *Bufonariella* Thiele, 1929. *Bufonariella scrobilator* is undoubtedly congeneric with the type of *Tutufa* Jousseaume, 1881, and as Jousseaume's name is almost 50 years older, there is no problem here.

The type of *Tutufa* was originally designated as *Tutufa lampas* (L.), but the identity of that species is clouded in the usual Linnaean fashion. In fact, two distinct families were involved in the confusion of "*Murex lampas* Linné" and "*Triton lampas* Lamarck," ostensibly the same form. Dodge (1957, pp. 103-105), in his review of the Linnaean species, identified true *Murex lampas* Linné as the cymatiid *Triton nodiferum* Lamarck, and the "*Murex lampas*" of authors, *i.e., Triton lampas* Lamarck, as the bursid species for which the name *Murex rubeta* Linné would seem to be the best choice. This group was the subject of a study by E. A. Smith (1914) and, as first revisor, he restricted *rubeta (i.e., "lampas")* to the form well-figured in Chemnitz, v. 4, figs. 1236, 1237. Thus the type of *Tutufa* Jousseaume is correctly denominated as *Tutufa lampas* Jousseaume, = *Murex lampas* of authors not Linné, = *Murex rubeta* Linné.

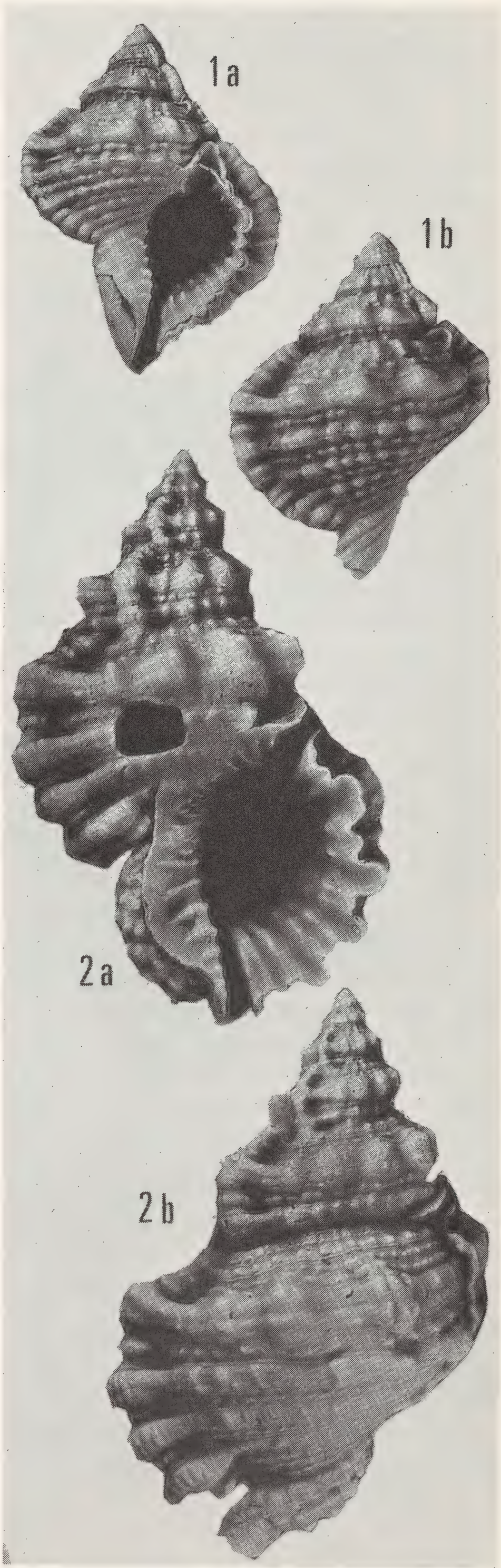
The type of *Bursa s.s., B. bufonia* (Gmelin), is a peculiar species with extreme development of the anal gutters, almost to the point of being tubes, although never completely closed. The varices are diametrically opposed and aligned up the spire. In *Tutufa* the gutters are less well developed and the most noticeable difference is the non-aligned varices. Following Thiele (1929-1931), Wenz (1941, pp. 1072-1073) placed *Tutufa* and *Lampas* Schumacher (non *Lampas* Montfort, 1808, a foraminifera) in the synonymy of *Bursa s.s.* and recognized *Bufonariella* as the valid subgenus for the bursids with non-aligned varices.

Woodring (1959, p. 207) has suggested that the subgeneric name *Colubrellina* Fischer, 1884 (type: *Ranella candisata* Lamarck = *Murex conditus* Gmelin), is best for the *B. caelata* group. However, the writer questions that assignment. The type of this subgenus is an extremely elongated shell, with fine granular ornamentation and does not seem especially closely related to the members of the "*caelata*" group.

The nature of the shell ornamentation in the *B. caelata* group is so similar to that of *Tutufa rubeta* (Linné), plus the fact that the last varix does often show a tendency to appear in front of the equivalent varix on the penultimate whorl, that one wonders if *Tutufa* is not a better assignment for the *B. caelata* lineage in spite of the somewhat aligned varices. If this suggestion is not acceptable, then the alternative is another subgenus that has been largely overlooked (it is not in Wenz, for example) and that is *Dulcerana* Iredale, 1931 (type: *Ranella granifera* Lamarck).

In the Recent fauna of the Caribbean there is a common species, *B. cubaniana* (d'Orbigny) (also known as *granularis* Röding, but that name should be restricted to the Indo-Pacific form), that is definitely referable to *Dulcerana.* It has the varices perfectly aligned up the spire, and the ornamentation is chiefly spiral rows of small granules. This species shows considerable variation in the nature of these spiral granules. In the Tulane collections there are some 100 specimens from the Panamá region (TU R-93, R-94, R-109, R-197) and among these there are examples that perfectly match d'Orbigny's original illustration, being covered with tiny bead-like spiral ribs; other examples are so coarsely ornamented that they approximate the sculpture of the *caelata* group but the over-all shell shape is still that of *B. cubaniana.*

Certainly there is no question of the placement of *B. pelouatensis,* the varices are completely non-aligned and the form is very close to the Recent *Tutufa rubeta.* In fact, if there were any purpose to be served by it one could insist that the Miocene form was well within the range of variation of the modern species. This is one of the biggest problems in all bursid taxonomy. There is a marked similarity in the spiral ornamentation among many of the species, which indicates that they all are descendants of a common ancestor. The ornamentation of the Peruvian Eocene and Oligocene forms differs but little from the Miocene *B. amphitrites* or the Recent *B. thomae.* The non-aligned varices of *B. pelouatensis* and *B. (Tutufa) lampas* seem to be clearly a random occurrence that appears from time to time in the group and probably has little if any taxonomic significance above the species level.



Text figure 1. *Bursa amphitrites* Maury, USNM 647109; height 22.2 mm, diameter 16.6 mm; locality TU 69A, Shoal River Formation, Florida; middle Miocene (X 2).
Text figure 2. *Bursa pelouatensis* (Cossmann and Peyrot), USNM 647108; height 48.3 mm, diameter 30.8 mm; locality TU 547, Chipola Formation, Florida; lower Miocene (X 1½).

It seems probable that the tubes of *Bursa s.s.* are also a random happening, which has occurred more than once. The ornamentation of *B. bufonia* is not closely allied to that of the *"caelata"* group, suggesting a far distant separation of that line. However, another of the Dominican species described by Maury (1917, p. 272, pl. 43, fig. 8) should be referred to *Bursa s.s.* as it has pronounced anal tubes. As its name *B. bufoniopsis* implies, it is much like *B. bufonia* but it has the *"caelata"* type of ornamentation and would seem to represent an independent development of the tubular structure. This conjecture is further advanced by a specimen from the upper Miocene of Trinidad, cited by Jung (1969, p. 486) as *B.* aff. *thomae* (d'Orbigny). This specimen has the ornamentation of the Recent *B. thomae,* but still has the anal tubes of *B. bufoniopsis* and presumably represents an intermediate stage. Morrison (1949, p. 11) placed *B. thomae* in *Bursa s.s.,* but the writer is of the opinion that as the species in question has no anal tubes it is better placed in the *"caelata"* group. There are no Recent species in either the western Atlantic or eastern Pacific that should be assigned to *Bursa s.s.*

In addition to the members of the true genus *Bursa,* in the Caribbean there are also representatives of the genus *Marsupina* Dall. The oldest known species was described from the Oligocene or early Miocene of Peru by Olsson (1932) and a third Dominican bursid was cited by Maury (1917, p. 272, pl. 43, figs. 6, 7) as "*B. crassa* Dillwyn" (= *spadecia* Montfort = *"Murex" bufo* Bruguière, 1792), which is the Recent type of the genus. Maury's species is probably *M. proavus* (Pilsbry, 1922), but it is clearly of the *Marsupina bufo* lineage. This group is also widespread in the Miocene to Recent faunas, having been reported from the Miocene of Santo Domingo (Gabb, Maury, Pilsbry), Costa Rica (Olsson), Trinidad (Maury, Jung), and the (?) Pliocene of Jamaica (Guppy, Pilsbry, Woodring).

BURSA (TUTUFA) PELOUATENSIS
(Cossmann and Peyrot)

Text Figure 1

Ranella scrobiculata "Kiener." GRATELOUP, 1847, Atlas, Conch. Foss. Bassin Adour, Ranelles, pl. 1 [pl. 29], fig. 10. [Not *Murex scrobiculator* Linné, 1767, = *M. scrobilator* Linné, 1758.]

NOT *Apollon subgranifer* d'Orbigny. COSSMANN, 1903, Essais Paléoconch. Comp., v. 5, p. 116, pl. 4, fig. 10. [Included by Cossmann and Peyrot, 1923, in the synonymy of *A. pelouatensis;* however, the specimen figured in 1903 is *A. inaequicrenatus* Cossmann and Peyrot, described at the same time also from Peloua.]

Apollon pelouatensis COSSMANN and PEYROT, 1923, Conch. Néogén. Aquitaine, *in* Soc. Linn. Bordeaux, Actes, v. 75, p. 309, pl. 15, figs. 38, 39; pl. 17, figs. 1, 2.

Figured specimen: USNM 647108; height 48.3 mm, diameter 30.8 mm; locality TU 547. Other occurrences in the Chipola Formation: TU locality nos. 546, 787, 830, 951, 1098 (all fragments except figured specimen and another small example also from TU 547).

BURSA (? TUTUFA) AMPHITRITES
Maury

Text figure 2

Bursa amphitrites MAURY, 1917, Bulls. Amer. Paleontology, v. 5, no. 29, p. 273 (109), pl. 43 (17), fig. 9. [Gurabo Formation, Dominican Republic; middle Miocene.]

Bursa amphitrites Maury. PILSBRY, 1922, Acad. Nat. Sci. Phila., Proc., v. 73, p. 360.

Bursa (Marsupina) albofasciata boussingaulti RUTSCH, 1934, Schweizer Palaeont. Gesell., Abh., v. 54, p. 58, pl. 3, figs. 3, 4. [Punta Gavilán Formation, Venezuela; Mio-Pliocene.]

Bursa (Colubrellina) caelata amphitrites Maury. WOODRING, 1959, U.S. Geol. Surv. Prof. Paper 306-B, p. 207, pl. 28, figs. 1, 2, 7, 8. [Gatun Formation, Panama; middle Miocene.]

[?] *Bursa (Colubrellina) caelata amphitrites* Maury. JUNG, 1965, Bulls. Amer. Paleontology, v. 49, no. 223, p. 513, pl. 68, figs. 12, 13; pl. 69, fig. 2. [Cantaure Formation, Venezuela; middle Miocene.]

Bursa (Marsupina) albofasciata boussaultingi Rutsch. JUNG, 1965, Bulls. Amer. Paleontology, v. 49, no. 223, pl. 69, fig. 1. [Paratype from Punta Gavilan.]

Figured specimen: USNM 647108; height 22.2 mm, diameter 16.6 mm; locality TU 69A, Shoal River Formation, middle Miocene.

LOCALITY DATA

The following are Tulane University fossil locality numbers:

69A. Shoal River Fm., first ravine upstream from Shell Bluff, Shoal River (NW ¼ Sec. 4, T3N, R21W), about 3½ miles north of Mossyhead, Walton Co., Florida.
546. Chipola Fm., Ten Mile Creek, about 1 3/4 miles west of Chipola River (NE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
547. Chipola Fm., west bank of Chipola River, about 2000 ft. above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
757. Gatun Fm., roadcut on south side Boyd-Roosevelt Highway at junction of road to Refineria Panama, S.A., just east of Cativa, Prov. of Colon, Panama.
787. Ten Mile Creek about 1½ miles west of Chipola River (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
830. Chipola Fm., Ten Mile Creek, at power line crossing about one mile west of Chipola River (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
951. Chipola Fm., Ten Mile Creek, about 1¼ miles west of Chipola River (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
954. Moín Fm., hill cut immediately behind Standard Fruit Co. box factory, just west of cemetery at Pueblo Nuevo, about 2 km west of Puerto Limon, Costa Rica.
958. Gatun Fm., hillslope on east side of road from Boyd-Roosevelt Highway to Refineria Panama, S.A., about ¼ km north of junction, just east of Cativa, Prov. of Colon, Panama.
1098. Chipola Fm., Ten Mile Creek, about 100 yards downstream from TU 830 (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.

The following are Tulane University Recent locality numbers. All are located on the Caribbean side of Panamá.

R-93. Holandes Cay, east of Cape San Blas, Panamá.
R-94. Duarte Cays, north island, north of Porto Bello, Panamá.
R-190. Fill for Refineria Panama, S.A., Bahia las Minas, Isla Payardi, Panamá (Radiocarbon dated at 7000 YBP).
R-197. Devil's Beach, west of Porto Bello, Panamá.

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April 11, 1973

REVIEWS

CONTRIBUTIONS TO THE HISTORY OF GEOLOGY, edited by George W. White, a series of classical works in geology, reprinted in facsimile with introductory biographical and bibliographical commentaries by the editor and other distinguished students of the history of geology. These volumes are handsomely and skillfully reproduced and are carefully selected to make essential but nearly unobtainable works available to students and historians at relatively modest cost. Published by Hafner Publishing Company, Inc., New York and London.

5. James Hutton's SYSTEM OF THE EARTH, 1785; THEORY OF THE EARTH, 1788; OBSERVATIONS ON GRANITE, 1794; together with Playfair's BIOGRAPHY OF HUTTON: facsimiles of the original editions, with an introduction by Victor A. Eyles and a foreword by George W. White, New York, 1970, xv + 203 pp., portrait, 2 pls., $12.95

This volume presents all of James Hutton's geological writings that have not been previously reprinted, making available to modern readers a complete collection of the geological works of the founder of geology. These works are virtually impossible to obtain in the original today, thus the importance of this volume cannot be overstated. Hutton set forth the principles of the Vast Continuum of geologic time, uniformity in geologic process, the role of heat and igneous activity as well as that of sedimentary process and erosion in shaping the earth, and the concept of the unconformity. Upon these fundamentals, through the medium of the important and explanatory *Illustrations of the Huttonian Theory of the Earth* (John Playfair, 1802), Charles Lyell based his *Principles of Geology* (1830-1833). Modern geology began (or was codified) with this series of works by Hutton, Playfair, and Lyell. Doctor Eyles discovered Hutton's unsigned and undated *Abstract* which is here reproduced and in the introduction summarizes his evidence that Hutton was the author and establishes the earlier date, 1785, for the first appearance of the Huttonian philosophy. This, the fifth of the classical reprint series, is one of the most important primary sources to have been reprinted in recent years.

6. TRAVELS THROUGH THE WESTERN COUNTRY IN THE SUMMER OF 1816, by David Thomas: facsimile of the 1819 edition. With an introduction by John W. Wells; a foreword by George W. White; and, *Notes on Thomas's Geological Observations* by John W. Wells and George W. White, New York, 1970, xviii + 338 pp., 3 folding charts, $14.95

This is one of the earliest books to describe and report on the origin of many geological features in western New York, northwestern Pennsylvania, Ohio and Indiana. Further, Thomas traveled entirely overland rather than by way of the Ohio River, thus observing regions previously unseen by anyone with scientific ability. His observations are geologic, economic, geographic, physiographic, and climatological, including such good descriptions of strata that they can be considered the first descriptions of geological formations in these areas. Doctor Wells's introduction reveals his intense interest and insight into David Thomas and his importance and influence on early science. Thomas was primarily devoted to agriculture and horticulture but his wide interest in other fields and his speculations about the origins of geological and other features makes his book quite significant and a worthy addition to the classic reprint series. Maps illustrating Thomas's route are included and his extensive notes which were not keyed to his text have been cross-indexed by professors Wells and White with marginal page numbers at the appropriate place in the text indicating where the notes appear in this version. A bibliography listing works cited or referred to by Thomas is appended.

H.C.S.

SCANNING ELECTRON AND OPTICAL MICROSCOPE PROCEDURE FOR VIEWING OF INDIVIDUAL COCCOLITHS

RONALD W. SHERWOOD and HAROLD L. LEVIN
WASHINGTON UNIVERSITY, ST. LOUIS, MISSOURI

ABSTRACT

A procedure is described for transferring specific nannofossil specimens from the light microscope to the scanning electron microscope. This technique permits high quality photomicrographs and scanning electron micrographs to be made of the same nannofossil specimen.

INTRODUCTION

It is axiomatic that special problems accompany the study of calcareous remains of nannofossils simply because of their small size (2-30 μ). One of these problems concerns the transfer of particular specimens from the stage of the light microscope to the sample grid or stud of an electron microscope so that the possibility of referring each of the two images to different taxa may be avoided. The technique described here permits one to examine and photograph a single specimen with both types of magnification systems.

TRANSFER OF SELECTED SPECIMENS FROM THE OPTICAL MICROSCOPE TO THE SCANNING ELECTRON MICROSCOPE

In 1967, Katharina Perch-Nielsen described a method for transferring particular specimens originally recognized by light microscopy to the specimen grid of the transmission electron microscope. The method described below differs considerably from the Perch-Nielsen method, and was developed for the scanning electron microscope.

1. Dilute sample to about 1 gram per 100 cc of distilled water, or until a droplet of suspension appears only slightly turbid. This dilution insures a sparse distribution of specimens and facilitates their relocation at later steps in the procedure.

2. With a capillary tube, add a drop or two of the suspension to a 12 mm diameter circular cover glass (No. 1 thickness, Thomas Scientific Apparatus Co.), which has been previously covered with a cushion of distilled water (Fig. 1a). Mix the fluids by blowing gently through the tube onto the liquid surface. Permit the suspension to dry. Three circular cover glasses can be placed on a microscope slide and prepared simultaneously. The glass containing the best distribution of specimens can then be retained for further processing.

3. The cover glass selected above is affixed to the center of a microscope slide by means of two tiny spots of Elmer's glue (Fig. 1c). (The smaller the amount of glue, the better.)

4. Place a drop of immersion oil (Cargille, R.I. 1.540) on the circular cover glass containing the dried sample.

5. Using a knife edge on a flat surface, break a No. 2 cover glass into thin shards, and glue these onto the microscope slide on either side of the circular cover glass.

6. Spot glue a 22 X 40 mm No. 1 cover glass onto the support shards. (Again, only a small amount of glue should be used since this rectangular cover glass must be removed later.) The SEM sandwich slide is now complete (Fig. 1b-c) and will provide excellent viewing and photography of coccoliths.

7. The SEM sandwich slide is next placed on the stage of the light microscope, one end is marked so that the slide can be replaced in the microscope in the same orientation during subsequent examinations. A traverse of the slide is made, noting the mechanical stage coordinates of clean, undamaged specimens.

8. After ten to fifteen specimens have been located, they are photographed.

9. Remove the sandwich slide from the microscope and cut the glue holding the rectangular cover glass to its shard supports. This should be done carefully with a razor blade.

10. Place the slide back on the microscope stage and, using the coordinates recorded in step 7, return to each selected specimen. (They will appear less distinct because of the absence of a cover glass.)

11. After centering the specimen at 500 X, inscribe a circle around it with a Leitz Object marker. This diamond-tipped tool should be set to inscribe the smallest circle possible (0.7 mm), (Fig. 1d).

12. After circling the desired specimens, remove the slide from the microscope, flush away the immersion oil with a stream of Ethanol, and allow to dry. This will also wash away loose particles which might settle on circled specimens. It has been our experience that not more than 10% of the circled specimens are lost during this flushing process.

13. Release the circular cover glass from the microscope slide by cutting the glue with a razor blade.

14. Place the cover glass with its circled specimens on a standard scanning electron microscope specimen stud and affix it to the stud on opposite sides with Elmer's glue. After the first glue spots have dried, completely encircle the exposed contact between the stud and cover glass with glue. Permit the glue to dry.

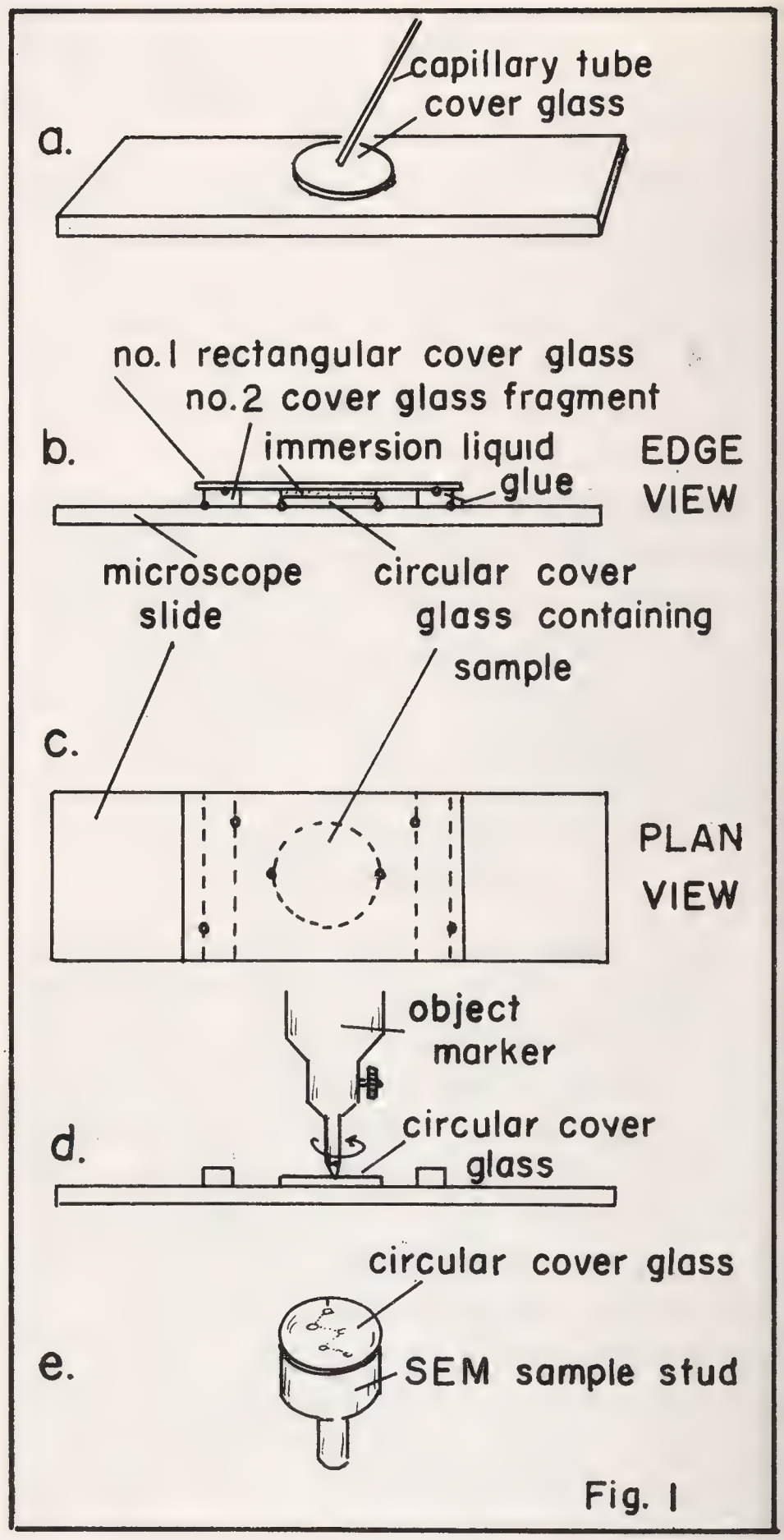

Fig. 1

15. Following standard procedures, coat the stud-mounted cover glass with carbon followed by gold, silver, or chromium.

PLATE 1. a. Scanning electron micrograph showing actual size of inscribed circle as seen in the SEM at 45 X. White arrow points to specimen of *Discoaster lodoensis* (same specimen in b, c, and d.) Note silver paint tangent to the right side of the inscribed circle. Point of black arrow indicates line made by diamond object marker. *b.* scanning electron micrograph, actual size of circle as seen in the SEM at 90 X, with specimen visible in the center of the circle. Note silver paint at far right of photo. *c. Discoaster lodoensis* Bramlette and Riedel, SEM micrograph, 3600 X. *d. Discoaster lodoensis* Bramlette and Riedel, phase contrast, oil immersion micrograph of specimen shown in Figs. a-c, 1800 X. Photograph of specimen taken on SEM sandwich slide mount. *e. Discoaster mirus* (Deflandre) Stradner and Papp, phase contrast, oil immersion micrograph, 1665 X. Taken of specimen on SEM sandwich slide mount. *f. Discoaster mirus* (Deflandre) Stradner and Papp, SEM micrograph, 4500 X, same specimen as in *e.*

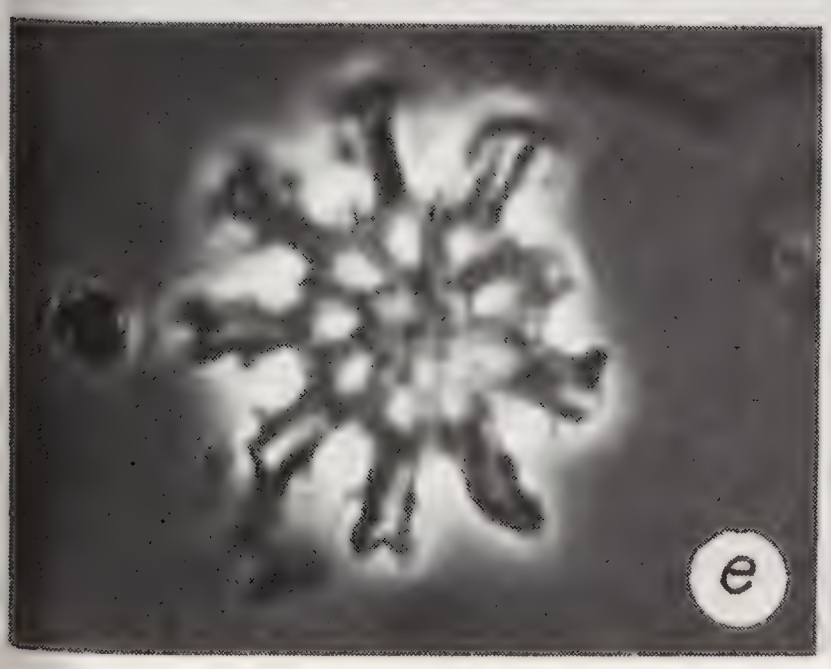

PLATE 1

16. Examine the coated stud with a low magnification stereoscopic microscope and place small drops of printed circuit silver paint next to the circles (Pl. 1, Figs. a,b). This will permit rapid relocation of the circles in the SEM. (Only very small amounts of silver paint should be used to prevent a charging problem.) A sketch of the position of the circles relative to some orientation mark will also facilitate relocation of the circles.

17. Place the sample in the SEM. At a magnification of 20 X, locate a circle on the stud. The circle will almost fill the field of view of the SEM at 200 X (Pl. 1, Figs. a,b). At 500 X, the specimen contained within the circle can be readily recognized.

Several advantages are realized by using this technique. First, the time-consuming scanning of samples can now be done with the light microscope and not consume SEM time. Second, the same specimen can be photographed with both the SEM and light microscope. Third, relocation of specimens is fast and accurate when subsequent examination is desired. Fourth, much of the tedious manipulation required in changing inclination and rotation of specimens during SEM photography is eliminated. Such changes may now be completed in one or two steps. Adjust the rotation and inclination controls to obtain the desired settings, focus on the stud, return to the circle containing the specimen, refocus, and photograph.

In 1971, Leffingwell and Hodgkin published an excellent technique for preparing palynomorphs for SEM study. The Leffingwell technique uses a micromanipulator to pick selected palynomorphs from dried residues. The picked palynomorphs are positioned on a circular cover glass previously ringed with guide circles. The cover glass is then attached to an SEM specimen stud, coated, and viewed in the SEM. While it is possible to pick nannofossils with the micromanipulator, there are several problems which we believe make the Leffingwell procedure less practical for nannofossil study than the one we have just presented.

In the dry state it is difficult to identify the much smaller (generally 5-20 μ) nannofossils; misidentification may reach fifty percent. Photomicrographs cannot be obtained of the specimens examined in the SEM and changing the orientation of specimens during SEM photography remains a tedious procedure.

ACKNOWLEDGEMENTS

This work was supported by a Grant-in-Aid of Research from the Society of Sigma Xi and the Washington University Graduate School Faculty Research Fund. The SEM was made available through Health Science Advancement Award F-304-FR 06115 to Washington University. We wish to thank Dr. Marie Greider and Mr. Edward Finke of the Department of Pathology, Washington University Medical School for their generous cooperation.

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April 11, 1973

TOWEIUS PETALOSUS NEW SPECIES, A PALEOCENE CALCAREOUS NANNOFOSSIL FROM ALABAMA

C. HOWARD ELLIS and WILLIAM H. LOHMAN
MARATHON OIL COMPANY, DENVER RESEARCH CENTER, LITTLETON, COLORADO

I. ABSTRACT

A new species of a minute calcareous nannofossil, *Toweius petalosus,* is described from the Paleocene Clayton Formation and Porters Creek Clay of western Alabama.

II. INTRODUCTION

A previously undescribed, morphologically distinct, very small, coccolith was observed in nannofossil examinations of a series of surface samples collected along the west bank of the Tombigbee River, just below the Demopolis Rooster Bridge on U.S. Highway 80, Sumter County, Alabama. At this locality the upper Cretaceous Prairie Bluff Chalk is disconformably overlain in turn by about five feet of the Clayton Formation and 20 feet of the Porters Creek Clay. These latter two formations have been correlated with the lower part of the Paleocene Midway Group (Toulmin, 1967).

Three samples contain specimens of the new species, *Toweius petalosus,* among their nannofossil assemblages. Two of the samples were obtained from the upper two feet of the Clayton Formation and one sample from an interval five feet above the base of the Porters Creek Clay. A total of several hundred specimens of this extremely small coccolith (1-2 microns), and associated coccospheres, were examined with the scanning electron microscope; the small size of *T. petalosus* n. sp. is beyond the resolution capabilities of the light microscope.

The authors thank Drs. David Bukry and Stefan Gartner, Jr. for their helpful suggestions during the early stages of this study; Dr. John L. Wray for critically reading the manuscript; and the Marathon Oil Company, Denver Research Center, for permission to conduct this investigation and to publish the results. Electron micrograph film negatives and prints of the holotype and paratypes are on file at the U.S. National Museum.

III. SYSTEMATIC DESCRIPTION

Family COCCOLITHACEA Kamptner, 1928

Genus TOWEIUS Hay and Mohler, 1967

TOWEIUS PETALOSUS
Ellis and Lohman, n. sp.

Plate 1, figs. 1-11

Description: Elliptical placolith with distal shield composed of 9 to 17 imbricate segments which terminate with a flat end; sutures between the segments have slight clockwise inclination if viewed on distal surface. Central pore also elliptical ranging from 0.47 to 0.87 microns in length; central area filled to varying degrees by extension of the proximal shield elements. From 9 to 17 large, high, petaloid plates originate from these central area segment extensions; they extend distally and radiate outward in a counterclockwise pattern. The petaloid plates expand in width toward their distal end with maximum width at about two-thirds the height of the plate. Plates extend beyond the lateral margin of the distal shield giving a crown-like appearance to the placolith in side view. A grille containing from 16 to 21 pores spans the central area on the proximal side. The proximal shield is composed of about the same number of segments as the distal shield and is slightly smaller. Observed specimens range from 1.2 to 1.9 microns in total length and 0.9 to 1.6 microns in total width; the petaloid plates range from 0.5 to 1.4 microns in height above the upper surface of the distal shield.

Coccospheres composed of from 42 to 54 placoliths are commonly devoid of placoliths at one pole. The petaloid plates of individual placoliths intermesh with those of adjoining placoliths or remain separated. Coccospheres range from 5.6 to 8.2 microns in diameter.

Over 60 SEM micrographs were used in determining measurements and in describing this new species.

Remarks: This distinctive species is different from any other described forms by virtue of the large petaloid plates which are present on the distal surface of the placolith and by its very small size. *Toweius petalosus* n. sp. also differs from *T. craticulus* Hay and Mohler, *T. eminens* (Bramlette and Sullivan), *T. helianthus* (Hay and Towe) and *T. tovae* Perch-Nielsen by being from one-half to one-fifth their size and by having only about one-fourth the number of shield segments. Because of its extremely small size, an electron microscope is required for the identification of *Toweius petalosus* n. sp.

The five species of *Toweius,* including *T. petalosus* n. sp., have been reported from Paleocene and lower Eocene sediments. The geographic occurrences of the various species include California, Alabama, France, England, and Poland.

Age and Occurrence: Numerous individual placoliths as well as entire coccospheres have been observed in samples of the Paleocene Clayton Formation and Porters Creek Clay of Sumter County, Alabama.

Dimensions: Holotype–length, 1.5 microns; width, about 1.3 microns.

Holotype: Plate 1, figure 1; USNM 175747.

Paratypes: Plate 1, figures 2-11; USNM 175748, 175749, 175750, 175751, 175752, 175753, 175754, 175755, 175756, 175757.

Type Locality and Level: Five feet above the base of the Paleocene Clayton Formation, west bank of the Tombigbee River below Demopolis Rooster Bridge on U.S. Highway 80, Sumter County, Alabama.

PLATE 1

Figures

1-11 *Toweius petalosus* Ellis and Lohman, n. sp.
(1) holotype, distal surface. Clayton Formation, X 20,000; USNM 175747. (2) paratype, distal surface. Clayton Formation, X 20,000; USNM 175748. (3) paratypes, distal surface of several specimens, absence of petaloid plates on one specimen shows central pore area and sutures on distal shield surface. Clayton Formation, X 17,500; USNM 175749. (4) paratypes, partial coccosphere showing intermeshing of petaloid plates of adjoining placoliths. Clayton Formation X 7,500; USNM 175750. (5) paratypes, proximal surfaces showing grille with pores covering central area. Clayton Formation, X 10,000; USNM 175751. (6) paratypes, proximal surfaces showing central area grille and sutures on proximal shield surface. Clayton Formation, X 17,500; USNM 175752. (7) paratype, lateral view showing petaloid plates. Porters Creek Clay, X 15,000; USNM 175753. (8) paratype, lateral view showing petaloid plates extending beyond lateral margin of the two shields. Clayton Formation, X 20,000; USNM 175754. (9) paratype, lateral view showing crown-like appearance of placolith. Clayton Formation, X 15,000; USNM 175755. (10) paratypes, coccosphere devoid of placoliths at one pole. Porters Creek Clay, X 9,000; USNM 175756. (11) paratypes, coccosphere showing some placoliths with poorly developed petaloid plates. Porters Creek Clay, X 7,000; USNM 175757.

PLATE 1

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April 11, 1973

RECENT BOOKS RECEIVED

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GLOBAL GEOPHYSICS, by R. H. Tucker, A. H. Cook, H. M. Iyer and F. D. Stacey. Published by American Elsevier Publishing Company, Inc., New York, 1970, vii + 199 pp., illus., $7.00

PRINCIPLES OF PHYSICAL GEOGRAPHY, by F. J. Monkhouse. Published by American Elsevier Publishing Company, Inc., New York, 1970, ix + 570 pp., illus., $8.00

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STRAIN FACIES, by Edward Hansen, *Minerals, Rocks and Inorganic Materials,* volume 2. Published by Springer-Verlag, New York, Heidelberg and Berlin, 1971, x + 209 pp., 78 figs., 21 plates, $16.80

SALT DEPOSITS, THEIR ORIGIN AND COMPOSITION, by O. Braitsch, translated by P. J. Burek and A. E. M. Nairn, *Minerals, Rocks and Inorganic Materials,* volume 4. Published by Springer-Verlag, New York, Heidelberg and Berlin, 1971, xiv + 297 pp., 47 figs., $20.80

RESEARCH TECHNIQUES FOR HIGH PRESSURE AND HIGH TEMPERATURE, edited by Gene C. Ulmer. Published by Springer-Verlag, New York, Heidelberg and Berlin, 1971, xii + 367 pp., $10.00

NOMENCLATURAL CHANGES IN MARGINELLIDAE (MOLLUSCA: GASTROPODA)

BARRY ROTH
SAN FRANCISCO, CALIFORNIA

The following names are introduced as replacements for preoccupied specific and subspecific names in the gastropod family Marginellidae:

PRUNUM LIPARUM LEPTOCHILUS

Roth, *nom. nov.*

Marginella (Egouena) lipara lepta GARDNER, 1938, U.S. Geol. Surv. Prof. Paper 142-F, pp. 396-397, pl. 47, fig. 8.
Not *Marginella lepta* BARTSCH, 1915, U.S. Natl. Mus., Bull. 91, p. 40, pl. 21, fig. 3.

Type locality: Miocene, Chipola Formation, one mile below Bailey's Ferry, Chipola River, Calhoun County, Florida [= TU 457].

Gardner separated this subspecies from *Prunum liparum* (Gardner, 1938) by "its conspicuously slender outline." The height-diameter ratio of the holotype of *P. liparum leptochilus* (1:0.53) is slightly greater than that of the holotype of the nominate subspecies (1:0.55). A clearer distinction may be the shape of the outer lip, which is sharply flexed and somewhat produced posteriorly in *P. liparum*, gently flexed and not produced in the present subspecies.

Woodring (1970) placed *Egouena* Jousseaume, 1875, in synonymy with *Microspira* Conrad, 1868, treating the latter as a subgenus of *Prunum* Herrmannsen, 1852. The moderately elevated spires of *P. liparum* and *P. l. leptochilus* suggest their placement in the genus *Prunum* in the strict sense.

PERSICULA AMPLIOR

Roth, *nom. nov.*

Marginella (Persicula) majuscula GARDNER, 1938, U.S. Geol. Surv. Prof. Paper 142-F, pp. 399-400, pl. 47, fig. 24.
Not *Marginella majuscula* MARTENS, 1877, Möbius Beitr. Meeresf. Maurit., pp. 257-258, pl. 22, fig. 2.
Not *Marginella miliaria* var. *majuscula* "Monts." [Monterosato]. BUCQUOY, DAUTZENBERG & DOLLFUS, 1883, Les Mollusques Marins du Roussillon, v. 1, fasc. 3, p. 123.

Type locality: Miocene, Oak Grove Sand, Oak Grove, Yellow River, Okaloosa County, Florida [= TU 91].

The holotype is an immature shell with an incompletely calloused outer lip. Adult specimens should be recognizable by an evenly ovate outline, in contrast to the pyriform shape of *Persicula progravida* (Gardner, 1938) from the Oak Grove Sand and to the angled periphery of *Persicula calhounensis* Maury, 1910, from the Chipola Formation.

DENTIMARGO EOS Roth, *nom. nov.*

Marginella aurora THIELE, 1925, Wissenschaftliche Ergebnisse der Deutschen Tiefsee-Expedition auf dem Dampfer "Valdivia" 1898-1899, Bd. 17, Heft 2, p. 197 (163), pl. 34 (22), fig. 9.
Not *Marginella aurora* DALL, 1890, Wagner Free Inst. Sci., trans., v. 3, part 1, p. 51, pl. 6, fig. 4a.

Type locality: Recent, off east Africa, 6° 34.8' S, 39° 35.5' E, in 404 meters; and 5° 27.9' S, 39° 18.8' E, in 463 meters.

This species is assigned to *Dentimargo* Cossmann, 1899, although it appears to lack the toothed outer lip sometimes considered typical of that genus. The genus *Longinella* Laseron, 1957, was proposed for species lacking such dentition, but that name is itself a homonym. Several authors have commented on the unreliability of marginal dentition as a generic, or even a specific, character in the family Marginellidae.

"MARGINELLA" PEMPHIX Roth, *nom. nov.*

Marginella ovata THIELE, 1925, Wissenschaftliche Ergebnisse der Deutschen Tiefsee-Expedition auf dem Dampfer "Valdivia" 1898-1899, Bd. 17, Heft 2, p. 198 (164), pl. 34 (22), fig. 11, text fig. 8.

Not *Marginella ovata* I. LEA, 1833, Contributions to Geology, p. 179, pl. 6, fig. 191.

Not *Marginella ovata* EMMONS, 1858, Rept. North Carolina Geol. Surv., p. 261, fig. 136.

Not *Marginella (Glabella) ovata* G. F. HARRIS, 1897, Cat. Tert. Moll. British Museum. Pt. 1. Australasian Tert. Moll., p. 88, pl. 4, figs. 6a, 6b.

Type locality: Recent, off east Africa, 1° 40.6' S, 41° 47.1' E, in 693 meters; and 1° 48.2' N, 45° 42.5' E, in 1644 meters.

Until more is known about the relationships within the family, this species cannot receive exact generic placement. It does not belong in *Marginella* in the strict sense. The radula (Thiele, 1925, text fig. 8) falls between the straight, comblike rachidian plates recorded for species of *Volvarina* Hinds, 1844, and *Prunum,* and the chevron-shaped plates seen in species assigned to *Alaginella* and *Austroginella* Laseron, 1957.

GRANULINA GLUMA Roth, *nom. nov.*

Marginella globulosa THIELE, 1925, Wissenschaftliche Ergenbisse der Deutschen Tiefsee-Expedition auf dem Dampfer "Valdivia" 1898-1899, Bd. 17, Heft 2, p. 199 (165), pl. 34 (22), fig. 17.

Not *Marginella globulosa* KOENEN, 1890, Abhandl. geol. Special-karte Preussen u. Thuring. Staaten, Bd. 10, Heft 2, Lief. 2, p. 552, pl. 38, figs. 12a, 12b.

Type locality: Recent, off east Africa, 5° 27.9' S, 39° 18.8' E, in 463 meters; and 5° 55.8' S, 39° 1.2' E.

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April 11, 1973

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Volume 10, Number 3 September 7, 1973

CALCAREOUS NANNOFOSSILS AND LATE PLIOCENE-EARLY PLEISTOCENE BIOSTRATIGRAPHY LOUISIANA CONTINENTAL SHELF

JULES B. SACHS
and
HUBERT C. SKINNER
TULANE UNIVERSITY

p. 113

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JULES B. SACHS
and
HUBERT C. SKINNER[1]

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HAROLD E. VOKES, Department of Geology, Tulane University, New Orleans, Louisiana

[1]Names arranged alphabetically; no seniority implied.

ABSTRACT

The vertical distributions of calcareous nannofossils and pertinent planktonic foraminifers within the late Neogene strata of the Louisiana Continental Shelf were studied and compared with that in other areas including the type section of the Pleistocene in southern Italy. Thirty-two species of nannofossils from twenty genera are identified and illustrated from sidewall core samples taken from four wells drilled in the Ship Shoal Area, offshore Terrebonne Parish, Louisiana. Though the ranges of nine of these species are considered stratigraphically significant, only the extinction of *Discoaster brouweri* Tan Sin Hok and the approximate first appearance of *Gephyrocapsa caribbeanica* Boudreaux and Hay are recognized as useful stratigraphic criteria for delineating the Pliocene-Pleistocene boundary in this area. A new formation, the Terrebonne Shale, is described from the basal Pleistocene section on the Louisiana Continental Shelf. Other results include: 1) delineation of a phylogenetic series extending from *Coccolithus doronicoides* Black and Barnes in the middle Pliocene section to *Emiliania huxleyi* (Lohmann) in the Holocene; 2) recognition of the co-occurrence of *Ceratolithus cristatus* (Kamptner) and *Ceratolithus rugosus* Bukry and Bramlette in the earliest Pleistocene sediments; 3) extension of the geologic range of *Gephyrocapsa protohuxleyi* McIntyre and *Cricolithus jonesi* Cohen back to the early Pleistocene; 4) the first reported fossil record of *Homozygosphaera wettsteni* (Kamptner) and *Calyptrosphaera oblonga* Lohmann; and, 5) generic reassignment of *Coccolithus productus* (Kamptner), n. comb., and *Cristallolithus macroporus* (Deflandre), n. comb.

I. INTRODUCTION

The Pleistocene sedimentary deposits of the Louisiana Gulf Coast have been the subject of numerous investigations. Most of these studies, however, have dealt with non-marine alluvial terraces deposited during the interglacial stages. Relatively few studies pertain to the marine equivalents of the non-marine terraces. Although several investigators have referred to the base of the marine Pleistocene ("Upper Marine") beds, definitive paleontological studies of the Louisiana Continental Shelf sediments have been undertaken only by Akers and Holck (1957), Akers and Dorman (1964), Akers (1965), Wray and Ellis (1965), Sachs (1970), and Poag (1971, 1972).

In 1963, Ericson, Ewing, and Wollin postulated that the Pliocene-Pleistocene boundary can be recognized in deep-sea cores based on certain changes among the planktonic foraminifers and upon the extinction of discoasters. Since 1963, more than fifty papers, primarily concerned with planktonic foraminifers, have been written on the boundary problem with the authors taking positions for or against the hypothesis of Ericson *et al.* as well as employing other criteria for recognition of the Pliocene-Pleistocene boundary, namely paleomagnetism, radiolarians, and calcareous nannofossils.

More than eighteen years have elapsed since Bramlette and Riedel (1954) suggested that calcareous nannofossils could be used to determine stratigraphic horizons. In the interim, hundreds of investigations have been published; until quite recently, however, relatively few have dealt with late Neogene strata from the marine epicontinental environment.

The present study was undertaken to establish or recognize biostratigraphic zones within the lower marine Pleistocene section on the Louisiana Continental Shelf by comparing the distribution of calcareous nannofossils and pertinent planktonic foraminifers with their distributions in other areas including the type section of the Pleistocene in southern Italy. The objectives of this study, therefore, were as follows:

1) to describe the calcareous nannofossils from the late Neogene strata of the Louisiana Continental Shelf and to compare these assemblages with those from the type section of the Calabrian of Italy and with equivalent sections in other areas;

2) to establish stratigraphic divisions within the strata underlying the Louisiana Continental Shelf and to determine the position of the Pliocene-Pleistocene boundary in this area; and,
3) to review current opinions and the data from other recent studies and publications on the Pliocene-Pleistocene boundary problem and to evaluate these opinions and data in respect to the results of the present study.

II. RECOGNIZING THE PLIOCENE-PLEISTOCENE BOUNDARY

Ericson, Ewing, and Wollin (1963) suggested that quantitative analyses of temperature-sensitive microfossils in deep-sea cores could be used to measure the duration of the Pleistocene Epoch. Of the 3000 cores they examined, only eight contained an interface that was marked clearly by an abrupt change in the fossil assemblages. They concluded that this interface is the Pliocene-Pleistocene boundary and that it can be recognized in deep-sea cores on the basis of the following paleontological criteria:

1) change in the coiling direction of the *Globorotalia menardii* "complex" from 95 percent dextral below, to 95 percent sinistral above the interface;
2) extinction of the genus *Discoaster* at, or just above, this boundary;
3) the presence of forms resembling both "*Globorotalia menardii* var. *miocenica*" and *Globorotalia menardii multicamerata* below the interface, but only forms similar to the living *Globorotalia menardii menardii* present above the interface;
4) the larger average diameter of tests of *Globorotalia menardii* above the boundary, coupled with a reduction in the percentage represented by this species in the total foraminiferal assemblage;
5) the presence of abundant *Globorotalia truncatulinoides* only above the interface; and,
6) the occurrence of *Globigerinoides sacculifer fistulosus* which is present only below the suggested boundary.

Ericson *et al.* estimated the beginning of the Pleistocene at not less than 800,000 years ago.

Later in 1963, Bandy compared planktonic assemblages near the Miocene-Pliocene boundary in deep-sea cores from the Philippines with the material that Ericson, Ewing, and Wollin (1963) had examined from the Atlantic. He concluded that the planktonic foraminifers below the boundary of Ericson, Ewing, and Wollin were of late Miocene age and he attributed the absence of discoasters above the interface to the presence of a disconformity between the Miocene and Pleistocene sediments in the Atlantic cores.

Riedel, Bramlette, and Parker (1963) utilizing two cores taken by the Swedish Deep-Sea Expedition in the tropical Pacific, reported extinction patterns similar to those of Ericson *et al.* (1963) but they were reluctant to identify the Pliocene-Pleistocene boundary until more data became available. However, they believed that these faunal/floral changes could be used as a provisional basis for correlation.

In 1968, Ericson and Wollin revised the criteria for delineating the Pliocene-Pleistocene boundary as established previously by Ericson, Ewing, and Wollin (1963). This revision was based in part on paleomagnetic studies on Atlantic and Antarctic deep-sea cores by Opdyke *et al.* (1966) and Glass *et al.* (1967) who demonstrated that these cores represented continuous sedimentation. Of five Atlantic deep-sea cores examined, one barely missed the boundary of Ericson *et al.* but the remaining four did reach this level, and two cores extended several hundred centimeters below the datum. All five cores are from the South Atlantic and can be correlated with each other. Ericson and Wollin (1968) based their revised concept of the Plio-Pleistocene boundary on the following factors:

1) the presence of abundant *Globorotalia truncatulinoides*, considered the *principal* criterion for recognition of

the base of the Pleistocene section;
2) the extinction of discoasters above the first abundant appearance of *Globorotalia truncatulinoides,* which is within the Nebraskan Stage; and,
3) the extinction of "*Globorotalia* sp. 1" above the "extinction of discoasters" and during the early Aftonian. [This form is a variant of *Globorotalia inflata* and initially was discussed and figured by Phleger, Parker, and Peirson (1953) as *Globorotalia* sp.]

The change in direction of coiling in the *Globorotalia menardii* complex from predominantly dextral in the Pliocene to predominantly sinistral in the Pleistocene occurs in the section some two meters below the first abundant *Globorotalia truncatulinoides* and the equivalent of their Pliocene-Pleistocene boundary. Ericson and Wollin interpreted this coiling change as evidence that climatic deterioration began in late Pliocene.

Variations in the relative abundance of the *Globorotalia menardii* complex are used by Ericson and Wollin to infer glacial and interglacial stages in the Pleistocene section, with high percentage occurrences indicating interglacial stages and low percentages corresponding to glacial stages. These authors still recognized, as they did in their earlier studies (1963 and 1964), the effects of four glacial and three interglacial stages, and maintained that extensive continental glaciation began in the early Pleistocene. In 1968, with the aid of paleomagnetic data, Ericson and Wollin revised their date for the beginning of the Pleistocene Epoch to 2,000,000 years B. P.

With regard to the extinction of discoasters within the Nebraskan, Ericson and Wollin (1968) made no reference to individual species; however, *Discoaster brouweri, Discoaster pentaradiatus,* and *Discoaster challengeri* are cited in a previous study as becoming extinct at the base of the Pleistocene (Ericson, Ewing, and Wollin, 1963) with *Discoaster brouweri* indicated as the last asterolith to become extinct.

The first data on the occurrence of Neogene discoasters in the Gulf Coast were published by Wray and Ellis (1965). They utilized cuttings from ten wells in the Ship Shoal and South Timbalier areas south of the central Louisiana Coast. Although cuttings are much less desirable than cores, they can permit recognition of extinction levels. Two levels of extinction were recognized which in the ten wells examined by Wray and Ellis are separated by 150 to 500 feet of section. The lower horizon is delineated by the last occurrence of *Discoaster exilis, Discoaster hamatus, Discoaster pentaradiatus, Discoaster surculus,* and *Discoaster variabilis,* in addition to a marked reduction in the abundance of *Discoaster brouweri.* The authors considered this horizon to be the top of the Pliocene interval. The upper level is marked by the extinction of *Discoaster brouweri.* Wray and Ellis were reluctant to state the precise age of this upper horizon as planktonic foraminiferal zones were not determined in their study.

The distribution of *Globorotalia truncatulinoides* on the Louisiana Continental Shelf has been studied by Akers and Dorman (1964), Akers (1965), and Poag and Akers (1967). They reported that the first appearance of this species is below the base of the marine Pleistocene sediments and that the first abundant appearance is at the base of the marine section. In addition, Akers (1965) recorded the distribution of discoasters in this area similar to that reported by Wray and Ellis, with *Discoaster brouweri* becoming extinct in the basal marine Pleistocene bed, which Akers interpreted as representing the first interglacial or the Aftonian Stage. Poag (1971) re-examined Akers's cores and postulated that several unconformities are present in this well. Nevertheless, the first abundant occurrence of *Globorotalia truncatulinoides* and the disappearance of *Discoaster brouweri* coincide at the base of the shale which Poag interprets as the base of the Pleistocene section.

In a short paper, Banner and Blow (1965) described twenty-three foraminiferal zones that have been widely cited in making intercontinental correlations. One of these,

N.22, is marked by the first appearance of *Globorotalia truncatulinoides* which they interpret as the immediate descendant of *Globorotalia tosaensis,* a relationship first noted by these authors in cores from the Philippines. They stated that zone N.22 is that "which we have recognized to occur in the lower part of the stratotype Calabrian of Santa Maria di Catanzaro, the agreed earliest Quaternary." This statement by Banner and Blow is the basis for most of the subsequent interpretation of this interface in deep-sea cores by various authors. Hays and Berggren (1971) maintained that the evolutionary transition from one species to another occurs only once and that extinctions and the non-evolutionary transition from *Globorotalia tosaensis* to *Globorotalia truncatulinoides* are the best paleontological criteria for recognizing the Pliocene-Pleistocene boundary.

The first definitive study of the Pliocene-Pleistocene interface utilizing calcareous nannofossils was by McIntyre, Bé, and Preikstas (1967) who selected for their study seven of the Atlantic deep-sea cores used by Ericson, Ewing, and Wollin (1963) in which the Pliocene-Pleistocene boundary was recognized. Not one of these seven cores, however, was used by Ericson and Wollin in 1968 in making their revised interpretation. In these seven cores, discoasters were present throughout the length of the section examined. Though the abundance of discoasters decreased markedly at the Ericson and Wollin boundary, all of the species persisted throughout the section studied. After detailed analysis of their results, McIntyre *et al.* concluded that the discoasters present above the boundary were reworked, as they are corroded, fragmented, and occur in clumps with clay acting as a binding agent. The discoasters occurring below this level are intact and are not worn. Furthermore, if discoasters were gradually becoming extinct, the sequential disappearance of various species could be expected.

In reviewing the distribution of coccoliths, McIntyre *et al.* recorded the extinction of *Cyclococcolithus leptoporus* var. A [now *Cyclococcolithina macintyrei* (Bukry and Bramlette)] and the disappearance of *Coccolithus pelagicus* at the boundary. They reported that the first species to appear in the basal Pleistocene is *Gephyrocapsa oceanica* [this variable taxon was later subdivided; *Gephyrocapsa caribbeanica* Boudreaux and Hay was erected for the early Pleistocene form].

Below the Pliocene-Pleistocene boundary the dominant species according to McIntyre, Bé, and Preikstas (1967) is *Coccolithus doronicoides* which constitutes 60 percent of the assemblage. Above this interface both *Coccolithus doronicoides* and *Gephyrocapsa caribbeanica* are present; *Gephyrocapsa caribbeanica* progressively replaces *Coccolithus doronicoides;* and, the two species together constitute 60 percent of the assemblage. The writers agree (see discussion of *Gephyrocapsa caribbeanica)* with McIntyre *et al.* that *Coccolithus doronicoides* is the progenitor of *Gephyrocapsa caribbeanica* and that it is replaced in part by the latter species as a constituent of the assemblage.

From their earlier studies, McIntyre, Bé, and Preikstas (1967) made the following pertinent observations about the ecology of coccolithophores:

1) *Gephyrocapsa oceanica* has preference for warmer waters;
2) *Coccolithus pelagicus* is restricted to areas north of the 14 degree isotherm in the North Atlantic Ocean; and,
3) *Cyclococcolithina macintyrei* is present in sub-antarctic waters.

These statements indicate that the assemblages in the strata above the boundary of Ericson, Ewing, and Wollin (1963) represent warmer waters than the assemblages below this interface.

McIntyre, Bé, and Preikstas (1967) concluded that:

1) the appearance of one new species following the disappearance of two other species, together with minor changes in the abundance of five species, represents sufficient change in the assemblage to justify the term "boundary"; and,

2) ecologically the assemblage below this interface represents colder conditions than the assemblage above; therefore, this horizon is the Nebraskan-Aftonian boundary instead of the Pliocene-Nebraskan boundary.

The present writers are in basic agreement with McIntyre, Bé, and Preikstas but cannot substantiate the distribution of *Coccolithus pelagicus* which is represented by extremely low percentages in the late Pliocene and the early Pleistocene of the Louisiana Gulf Coast. It is difficult to compare the statistical data of McIntyre *et al.* (1967) with that of other workers. Most workers combine light microscopy with electron microscopy, using the information obtained under the light microscope to compile statistical data; McIntyre *et al.* relied solely on the electron microscope for the statistical studies. Their interpretation of the first appearance of *Gephyrocapsa caribbeanica* in the early Pleistocene, agrees with the distribution of this species on the Louisiana Continental Shelf and in most other areas.

In June, 1964, the personnel of the Texas A & M University research vessel *Alaminos* obtained a 550 cm long core (No. 64-A-9-5E) from the largest of the Sigsbee knolls. In a preliminary paper, Bryant and Pyle (1965) reported *Discoaster brouweri* and *Discoaster pentaradiatus* as the dominant species throughout the core. In 1966, Pyle published the stratigraphic distribution of calcareous nannofossils from this core. He recorded nineteen species, of which six are discoasters. Unfortunately, the sediments above 150 cm in his core were disturbed and mixed with older sediments during extrusion from the core barrel which had been bent during the coring operation. The sediments above this level have been assigned by Pyle to the post-Pliocene.

James L. Lamb (1969) examined the planktonic foraminifers from the upper portion of this same *Alaminos* core and dated his sample at 150 to 153 cm as post-Pliocene, and the sediments at 200 to 203 cm as late Pliocene in age. Pyle (1966) stated that because discoasters were present in considerable abundance above the 150 cm level in his core, the genus *Discoaster* did not become extinct at the end of the Tertiary. The distribution of the twelve heliolithid species as interpreted by Pyle (1966) needs little explanation. All are long-ranging and are characteristic of Neogene strata. One modification in the reported distribution was made by Pyle in 1968 when *Emiliania huxleyi* was noted in Pliocene and Pleistocene sediments. This change in interpretation is questionable, however, as the species first appears elsewhere in upper Pleistocene strata (Boudreaux, 1968; Gartner, 1969; and McIntyre and Bé, 1967).

Beard and Lamb (1968), in a controversial paper on the Pliocene-Pleistocene boundary in the Caribbean and the Gulf of Mexico, recognized the horizon at 192 cm in this same core. This level coincides with the extinction of *Globoquadrina altispira*, at the point which corresponds closely with the disappearance of other warm-water species, such as *Globoquadrina venezuelana* and *Globorotalia menardii,* and the appearance of the cold-water indicator *Globorotalia inflata.* The Aftonian-Nebraskan boundary was placed at 160 cm in the core based on the disappearance of *Globorotalia menardii multicamerata* and *Globorotalia menardii miocenica* and the appearance of *Globoquadrina dutertrei* and sinistrally coiled *Globorotalia menardii menardii.*

Beard and Lamb (1968), Beard (1969), and Lamb (1969), reporting on the same *Alaminos* core and on a 1000 foot long section cored by the Chevron, Gulf, Humble, and Mobil oil companies on the northwest Florida shelf, record a similar distribution of *Globorotalia truncatulinoides* to that of Akers (1965). Because of the controversial placement of the Pliocene-Pleistocene boundary by Beard and Lamb in core No. 64-A-9-5E, Pyle (1968) re-examined the core and reaffirmed his belief that the stratigraphic ranges of the discoasters agree with the interpretation of Akers (1965) and Wray and Ellis (1965) in that discoasters became extinct within the early Pleistocene.

In the present study, core samples from the Louisiana Continental Shelf were compared with material from the *Alaminos* core using

both the electron and light microscopes. It is concluded that the early Pleistocene beds on the Louisiana Continental Shelf are younger than the 150 to 160 cm interval that is called "Aftonian" by Beard and Lamb (1968) and "early Aftonian" by Lamb (1969). The bases on which the section from the Louisiana Continental Shelf is judged to be younger are as follows:

1) in the 150 to 160 cm segment in the *Alaminos* core from the Sigsbee knolls, discoasters are abundant; but discoasters are very rare in the Pleistocene strata on the Louisiana Continental Shelf;
2) five species of discoasters are identified in the 150 to 160 cm segment; but only rare specimens of one species, *Discoaster brouweri,* are present in the basal marine shale of the Louisiana Gulf Coast. The presence of rare specimens of [reworked] *Discoaster brouweri* in the early Pleistocene of the Gulf Coast section is substantiated by the work of Akers (1965) and of Wray and Ellis (1965). It may be argued that the Calabrian stratotype in Italy contains abundant and diverse discoasters; however, considerable reworking exists in this section (Smith, 1969). Thus, the evidence is insufficient to substantiate the presence of discoasters throughout the section in the type area;
3) no species of *Gephyrocapsa* were found in the 150 to 160 cm segment in the Sigsbee knolls core in either light or electron microscope examination. *Gephyrocapsa caribbeanica* occurs in the marine shale on the Louisiana Continental Shelf;
4) *Sphenolithus abies* is present in the 150 to 160 cm segment of the *Alaminos* core, but is unknown in Pleistocene and late Pliocene sediments elsewhere.

In 1963, twenty miles off the southwest coast of Jamaica, a long core taken by the drilling vessel *Submarex* penetrated 56.4 meters of sediment. Unfavorable weather hampered the drilling operations and only 20.7 meters (37%) of the core was recovered. Hay and Boudreaux (1968) reported that the preservation of the nannofossils was not good and that secondary overgrowths made identification of species difficult. Asteroliths are rare even in the lower portion of the recovered section. *Discoaster surculus, Discoaster variabilis,* and *Discoaster pentaradiatus* are extremely rare and are present only in the basal portion of the core. A few reworked older discoasters such as *Discoaster tani* and *Discoaster deflandrei,* were also recorded. According to Hay and Boudreaux, "the only obvious change in the nannoplankton of the core is the ultimate extinction of *Discoaster brouweri* and the disappearance of *Coccolithus pelagicus* at 23.5 meters." Boudreaux (1968) placed the Pliocene-Pleistocene boundary at this level in the core. *Gephyrocapsa caribbeanica* is reported common down to 29 meters in this core (Boudreaux, 1968) and "sparse" down to the base of the core at 56.4 meters.

The *Coccolithus doronicides* complex, which Gartner (1969), McIntyre *et al.* (1967), and Sachs (1970) report as abundant in lower Pleistocene and upper Pliocene sediments was not recorded initially from this core. Re-examination of the samples, however, revealed its presence as a minor constituent of the assemblage.

Bolli, Boudreaux, Emiliani, Hay, Hurley, and Jones (1968), reported on the planktonic foraminifers in the same *Submarex* core. they noted that *Globorotalia truncatulinodes* is present throughout the entire interval, but attributed the occurrence of *Globorotalia truncatulinoides* to environmental conditions. According to these authors, the lower portion of the core at 4753 to 5634 cm correlates with the Manchioneal Formation of Jamaica based on the joint occurrence of *Globoquadrina altispira* and *Globorotalia truncatulinoides.* Such combined occurrence of these two species was not recognized in the studies by Parker (1967); Banner and Blow (1967); Blow (1969); Beard and Lamb (1968); Hays, Saito, Opdyke, and Burckle (1969); Beard (1969); and others. In addition, Robinson (1968) and Lamb (1969) do not report the presence of *Globoquadrina altispira* in the Manchioneal Formation and both authors consider this formation to be

early Pleistocene in age. Bolli *et al.* (1968), in reviewing the distribution of planktonic foraminifers in this core, state that the "upper portion of the *Submarex* core (from 549 to 4174 centimeters) cannot yet be correlated with known marine epicontinental deposits."

Poag (1971) and other workers, have recently demonstrated that the extinction of *Globoquadrina altispira* occurs below the first appearance of *Globorotalia truncatulinoides* in the northern Gulf of Mexico. This interpretation agrees with the work of Beard (1969) and Lamb(1969). the distribution in the *Submarex* core, namely the rare occurrence of *Discoaster brouweri,* the "extremely rare" occurrence of other discoasters, and the presence of both *Gephyrocapsa caribbeanica* and *Globorotalia truncatulinoides* throughout its length, lead to the suggestion that the core is Pleistocene in age and that the presence in this core of *Globoquadrina altispira, Sphenolithus abies,* and older discoasters represent reworking. Considering the proximity of the *Submarex* core to the present coast of Jamaica, it is quite possible that the lowering of sea level during the early Pleistocene intensified reworking of the section.

III. THE JOIDES PROGRAM

Gartner (1969) published a calcareous nannofossil zonation of the Neogene strata utilizing samples from Leg 2 of the JOIDES program and piston cores from the Atlantic and Pacific oceans. He used the planktonic foraminiferal zonation of Blow (1969) because the samples had been dated previously according to Blow's zonation. The base of zone N.22, the first appearance of *Globorotalia truncatulinoides,* and the Tertiary-Quaternary boundary coincide with the base of Gartner's *Pseudoemiliania* zone. The base of his *Pseudoemiliania* zone is marked by the extinction of *Discoaster brouweri* and near the base of this zone the genus *Gephyrocapsa* first appears. The *Pseudoemiliania* zone replaces, in part, the *Gephyrocapsa caribbeanica* zone which Hay *et al.* (1967) had proposed earlier. Gartner maintains that the different species of *Gephyrocapsa* are not readily discernible with the light microscope and that the *Pseudoemiliania* zone is more suitable and recognizable for practical stratigraphic work.

From Leg 7, Martini and Worsley (1970, 1971) published another Neogene zonation of calcareous nannofossils. The portion for the upper Pliocene and Quaternary is almost identical with that of Gartner (1969). However, they reported that one sample from the *Discoaster brouweri* zone contained rare occurrences (less than one specimen per ten fields of view) of *Gephyrocapsa.* Hay, reporting on Leg 4, also noted that in a few samples rare specimens of *Gephyrocapsa caribbeanica* were found in the *Discoaster brouweri* zone. Bukry also worked extensively on the JOIDES cores, publishing on samples from Legs 1 through 8. Bukry and Bramlette (1970), and Bukry (1971a, 1971b) proposed a nannofossil zonation which included numerous subzones. Of particular interest is their subdivision of the late Pliocene and early Pleistocene into subzones.

Bukry (1971a) in an exemplary discussion of biostratigraphic zones, stated that his basis for subdivision of zones is "that advocated by M. N. Bramlette, which utilizes the specific character of an assemblage bounded by closely spaced multiple first and last occurrences." In this manner the whole assemblage is not affected by the presence or absence of any one species.

The top of the *Discoaster brouweri* zone of Bukry and Bramlette (1970) differs from that of other authors in that it is defined not on the last occurrence of *Discoaster brouweri* but on the marked reduction in numbers of *Discoaster brouweri, Discoaster pentaradiatus, Cylococcolithina macintyrei,* and *Ceratolithus rugosus.* In a similar vein the base of the *Coccolithus doronicoides* zone is characterized by abundance of *Coccolithus doronicoides, Cyclococcolithina leptora,* and *Emiliania annula;* and, when present, the paucity of *Discoaster brouweri, Gephyrocapsa caribbeanica, Cyclococcolithina macintyrei,* and *Ceratolithus rugosus.*

IV. THE CALABRIAN SECTION

At the Eighteenth International Geological Congress in 1948, it was recommended that

the Calabrian Formation should be considered as the lowest member of the lower Pleistocene Epoch (type locality, Santa Maria di Catanzaro in Calabria). The Calabrian originally had been considered as the youngest stage of the upper Pliocene by Gignoux (1910, 1913). The basis for this recommendation was the "reported" occurrence of two boreal forms, the bivalve *Arctica islandica* and the benthonic foraminifer *Hyalinea balthica*. These occurrences were believed to coincide with climatic deterioration in the Mediterranean area. Subsequent efforts at international meetings have failed to resolve the problem of selecting a type area for delineating the Pliocene-Pleistocene boundary. Therefore, at present, the Calabrian section of Santa Maria di Catanzaro remains the sole standard for recognition of this boundary.

Calabrian Bivalvia and Foraminiferida

As previously stated, Banner and Blow (1965) reported that the evolutionary transition from *Globorotalia tosaensis* to *Globorotalia truncatulinoides* was "recognized to occur in the lower part of the stratotype Calabrian." This brief statement was the only evidence offered to substantiate their position that the Pliocene-Pleistocene boundary should be recognized on the first appearance of *Globorotalia truncatulinoides*. Neither the stratigraphic distribution of species, location of the samples, frequency distributions, nor any other evidence was offered to justify or explain their position. It is upon this statement by Banner and Blow that *most* workers base their delineation of this horizon.

Bayliss (1969) in a study of the distribution of *Hyalinea balthica* and *Globorotalia truncatulinoides* in three sections in the Santa Maria di Catanzaro area, including the type locality, reports the presence in "undiminished numbers" of *Hyalinea balthica* 76 meters below the first appearance of *Arctica islandica*, the species that marks the base of the type Calabrian as defined by Gignoux (1910, 1913). *Globorotalia truncatulinoides* is rare in occurrence in all three of his sections and makes its first appearance at Santa Maria di Catanzaro at a point 50 meters above the base of Gignoux's Calabrian. One "questionable" specimen of *Globorotalia tosaensis* was identified in the underlying Pliocene beds. The ranges of both species were variable in all three sections and to Bayliss this "suggests that environmental controls other than the nature of the bottom deposits, viz. water depth affected the composition of the fauna."

Bayliss (1969) doubted the value of *Hyalinea balthica* and *Globorotalia truncatulinoides* as markers for the base of the Pleistocene, although he stated "they appear to be the best available and give a broad outline of the distribution of the Calabrian on a regional scale." Furthermore, he stated that

TABLE I

PLIOCENE-PLEISTOCENE ZONATION (after Bukry, 1971b)

	ZONE	SUBZONE
MIDDLE and LOWER PLEISTOCENE	Gephyrocapsa oceanica	
	Coccolithus doronicoides	Gephyrocapsa caribbeanica Emiliania annula
UPPER PLIOCENE	Discoaster brouweri	Cyclococcolithina macintyrei Discoaster pentaradiatus Discoaster tamalis

"if it is accepted that the first appearance of any one of the three species *Hyalinea balthica, Arctica islandica,* or *Globorotalia truncatulinoides* indicates the base of the Pleistocene, then the Pliocene-Pleistocene boundary has to be drawn below the lowest exposed beds in the Santa Maria di Catanzaro section, in which case it cannot coincide with Gignoux's horizon."

Lamb (1969) examined samples from the Calabrian stratotype and supported the interpretation of Bayliss (1969), although he reported the first appearance of *Globorotalia truncatulinoides* somewhat lower. Bandy and Wilcoxon (1970) examined samples from the Calabrian at Santa Maria di Cantanzaro and from a nearby section at Le Castella. At the type locality they restricted their sampling to the Calabrian as defined by Gignoux (1910, 1913) except for a single sample analyzed from just below the base of Gignoux's type Calabrian in the upper Pliocene sediments. They record once again that *Globorotalia truncatulinoides* makes its first appearance near the upper limit of the Calabrian, some 76 meters above the base of Gignoux's section. *Hyalinea balthica* was noted throughout the type section but was not recorded from the one sample in the upper Pliocene beds.

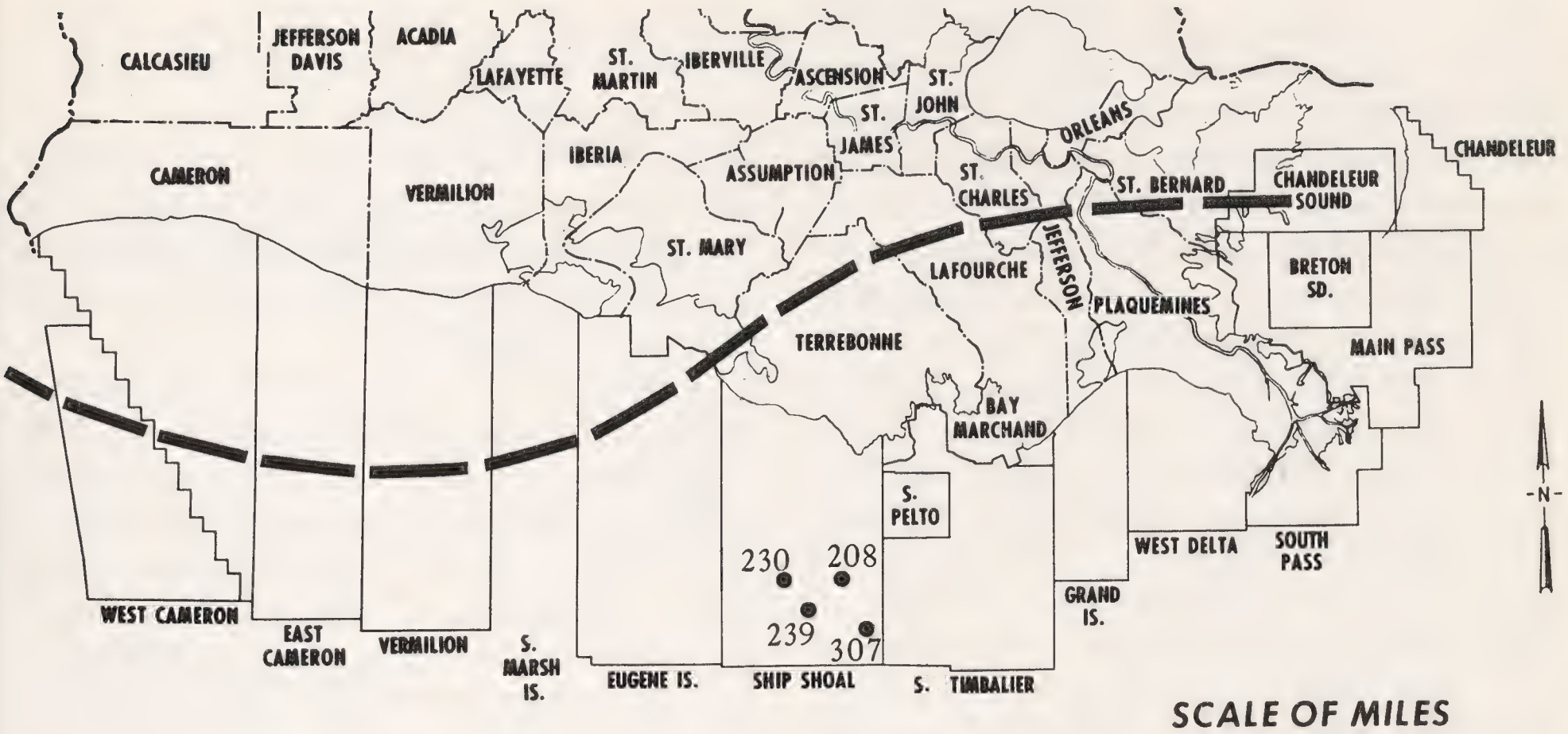
At Le Castella, Bandy and Wilcoxon sampled the entire section, taking one sample every meter for a total of 26 samples. Only one specimen of *Globorotalia truncatulinoides* was identified from all of their samples. *Hyalinea balthica* was recorded above what Bandy and Wilcoxon considered to be the Pliocene-Pleistocene boundary but was not recorded from the upper Pliocene strata. *Globorotalia tosaensis* was not reported by these authors from either the Calabrian stratotype or from Le Castella.

Calcareous Nannofossils

Hay and Boudreaux (1968) reported on three samples from the section at Le Castella. Two of these samples were located near Gignoux's Pliocene-Pleistocene boundary, one just above and the other just below the interface. The authors stated that, in addition to *Discoaster brouweri* both samples contained reworked assemblages of older discoasters. The third sample, located some 90 meters below the boundary, contained an "indigenous assemblage" which included *Discoaster surculus, Discoaster pentaradiatus, Discoaster brouweri,* and *Discoaster variabilis.* Hay and Boudreaux (1968) concluded that the extinction of discoasters occurs within the Pliocene, but that the level at which *Discoaster brouweri* becomes extinct cannot be determined precisely.

Smith (1969) published a study of calcareous nannofossils from the type Calabrian at Santa Maria Di Catanzaro and examined the Quaternary section at Le Castella. Lamb (1969), quoting Smith from a personal communication, stated that the sections in both areas are difficult to interpret as considerable reworking has occurred, and that "reworked floras are evident throughout the Pliocene and Early Pleistocene strata." Smith's reported distribution of discoasters at the stratotype reveals that, of the fifteen samples he examined (including four from the Pliocene), only *Discoaster brouweri* and *Discoaster variabilis* are found in every sample; *Discoaster exilis* occurs in the majority of the samples; *Discoaster surculus* is present intermittently through the section; and *Discoaster hamatus* was found in only a few of the samples.

Among the other calcareous nannofossils, Smith reports that "*Coccolithus* is the dominant form in the samples in the middle part of the section, whereas *Cyclococcolithus [Cyclococcolithina]* dominates the assemblage from Pliocene samples" as well as in the upper portion of the section. At Le Castella, Smith reported the presence of *Discoaster brouweri* in all 22 samples, *Discoaster surculus* in 16 samples, and *Discoaster exilis* in 15 of the samples. The distribution of coccoliths was reported as similar to that in the Calabrian section with three important exceptions. Smith noted the initial appearance of *Gephyrocapsa caribbeanica* in the upper portion of the section, and reported the presence of *Coccolithus lacunosus [Pseudoemiliania lacunosa]* and *Coccolithus exsectus [Coccolithus doronicoides]* intermittently through the section. From his study Smith (1969) draws the following conclusions:



LOUISIANA CONTINENTAL SHELF

Figure 1. Location of cored wells on the Louisiana Continental Shelf. The dashed line indicates the approximate northern limit of the Terrebonne Shale.

1) discoasters do not become extinct at the Pliocene-Pleistocene boundary as they occur in younger sediments;
2) the Calabrian section at Santa Maria di Catanzaro contains the Pliocene-Pleistocene boundary, is equivalent to the American marine Nebraskan based on the presence of *Globorotalia truncatulinoides* and *Discoaster brouweri,* and this section represents cool-water deposition;
3) at Le Castella, the strata are younger than the Calabrian at Santa Maria di Catanzaro based on the presence of *Discoaster brouweri* and *Gephyrocapsa caribbeanica,* and this section represents warm-water deposition.

Bandy and Wilcoxon (1970) supported Hay and Boudreaux's (1968) contention that discoasters became extinct at or near the Pliocene-Pleistocene boundary at Le Castella. Furthermore, they corroborated this extinction from their studies at Santa Maria di Catanzaro, the stratotype. At both localities they reported the presence of *Pseudoemiliania lacunosa* and *Gephyrocapsa caribbeanica* in both the Pleistocene and the Pliocene beds. Based on their study of the distribution of planktonic foraminifers and calcareous nannofossils at the type locality, Bandy and Wilcoxon concluded that the presence of three species, *Globorotalia truncatulinoides, Pseudoemiliania lacunosa,* and *Gephyrocapsa caribbeanica,* together with the absence of *Discoaster brouweri* and other discoasters, is sufficient to define the Pliocene-Pleistocene boundary. However, from the foregoing discussion of the many stratigraphic problems, it is obvious that clear definition of the Pliocene-Pleistocene boundary at the stratotype and at nearby exposed sections has not yet been accomplished and that controversy on this subject is certain to continue.

V. BIOSTRATIGRAPHY OF THE LATE PLIOCENE AND EARLY PLEISTOCENE, LOUISIANA CONTINENTAL SHELF

The Terrebonne Shale

The early Pleistocene deposits of southeastern Louisiana and the Louisiana Continental Shelf consist of basal regressive sandstones overlain by a thick marine transgressive shale unit, here named the Terrebonne Shale. This early Pleistocene shale which is overlain by later Pleistocene regressive sandstones is recognized only in the subsurface section south of the line indicated in Figure 1. The areal extent of the Terrebonne Shale and the underlying

regressive sandstones is more than 20,000 square miles. The shale varies in thickness from 100 feet to several thousand feet and near the northern limit of the shale wedge in southeastern Louisiana it lies at a depth of 1700 feet below sea level. The Pleistocene strata dip southward and thicken seaward to the southern portion of the continental shelf where the top of the Terrebonne Shale is encountered at depths greater than 10,000 feet. The combined thickness of the transgressive and regressive phases is more than 4000 feet, with the Terrebonne Shale alone exceeding 3000 feet in thickness in certain areas. In the southeastern portion of the Ship Shoal Area and in the South Timbalier Area the underlying regressive phase becomes predominantly shale so that the Terrebonne Shale expands to include both the transgressive and regressive phases in the downdip stratigraphic section.

Studies of the benthonic Foraminiferida from the Terrebonne Shale reveal that its environment of deposition varied from the inner shelf near its present updip extremity to that of the upper slope along the southern portion of the present shelf. The underlying regressive phase varied from the nearshore deltaic environment in the north to normal marine outer shelf in the south. The change from deltaic deposits to outer shelf deposits takes place over a relatively short distance. This leads to the conclusion that the pre-Terrebonne shelf was rather narrow.

The Terrebonne Shale is so visually apparent on electrical logs that in the updip position it is the only shale significantly expressed on such logs in either the Pliocene or Pleistocene section. The shale overlaps a large portion of the Pliocene strata, a relationship which has led most Gulf Coast stratigraphers to conclude that this transgressive marine shale represents the first interglacial stage in the Pleistocene and it is so interpreted in this study.

The Terrebonne Shale is markedly thicker and more extensive than later Pleistocene transgressive shale deposits. Its great thickness is attributed to two factors:

1) lowered sea level during the first Pleistocene glacial stage; and,
2) extensive erosion of updip Neogene marine and fluvial deposits due to increased stream gradients.

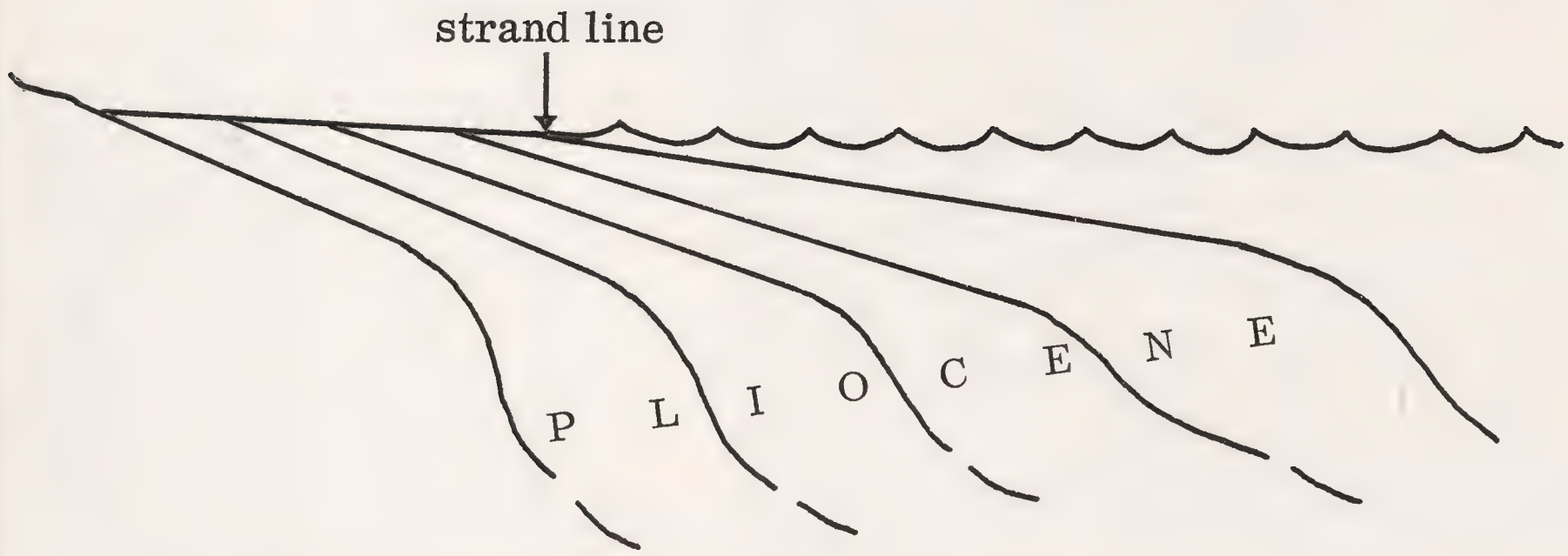
These two factors permitted more extensive invasion by the sea when sea level rose at the end of the first glacial stage and permitted the accumulation of the thick Terrebonne Shale sequence (see Figure 2).

Akers (1964) interpreted this shale as Aftonian in age and referred to it as the "upper marine" beds with credit to Lowman (1949, p. 1992, fig. 32). Sachs (1970) called it the Aftonian Shale. Poag (1971) renamed it the "Brouweri Shale." It cannot be shown to be Aftonian nor does *Discoaster brouweri* become extinct within the shale as interpreted by Poag. Further, a stratigraphic name must be based on a type locality and on a geographic place name and not on a species-group designation. These earlier names, therefore, are invalid. (ACSN, Arts. 10 and 13). The formal name here proposed is the Terrebonne Shale, based on the area of its best development in southern Terrebonne Parish, Louisiana, and in the contiguous offshore areas of the Louisiana Continental Shelf. The type log depicting the shale in the downdip position (see figure 3) is the Gulf Oil Corporation No. A-1 OCS 0498, located in South Timbalier Area Block 128, offshore Terrebonne. The top of the shale in the type section is encountered at -5850 feet and the base at -6890 feet, a total thickness of 1040 feet.

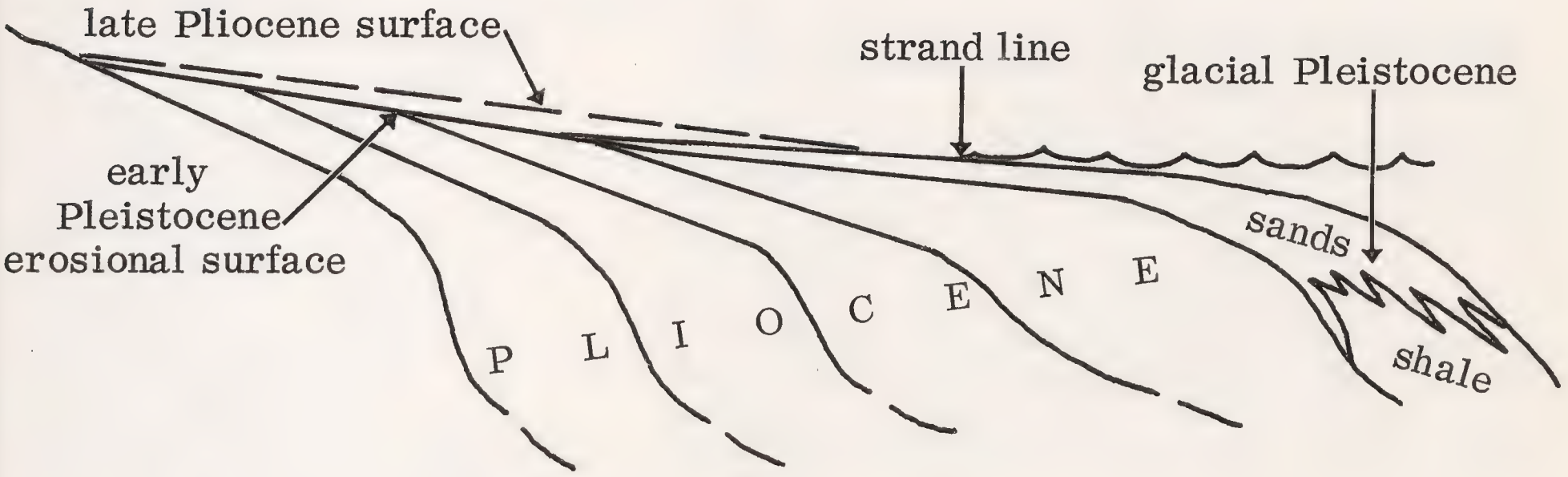
VI. SAMPLES AND PROCEDURE

The samples used for this study are 23 sidewall cores from four wells drilled more than 60 miles offshore from the present coastline in the southern portion of the Ship Shoal Area, offshore Terrebonne Parish, Louisiana (figures 1 and 4). These four wells are located in the Ship Shoal Area blocks 208, 230, 239, and 307.

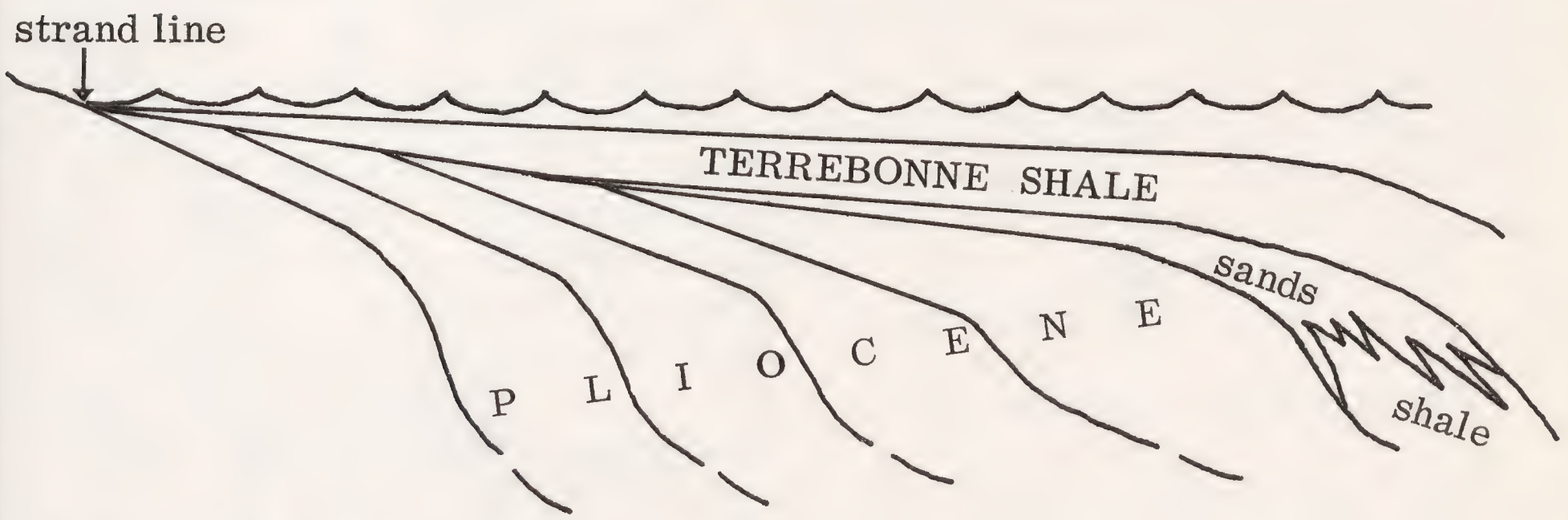
Three of the wells were correlated with each other by means of Induction-Electrical Logs to determine whether local facies changes occurred in this immediate area or whether the section penetrated in the Terrebonne Shale interval was faulted. The shale sequence is not interrupted by faulting



a. Late Pliocene



b. Glacial Pleistocene



c. Interglacial Pleistocene

Figure 2. Hypothetical diagram illustrating three stages of depositional history in the formation of the Terrebonne Shale.

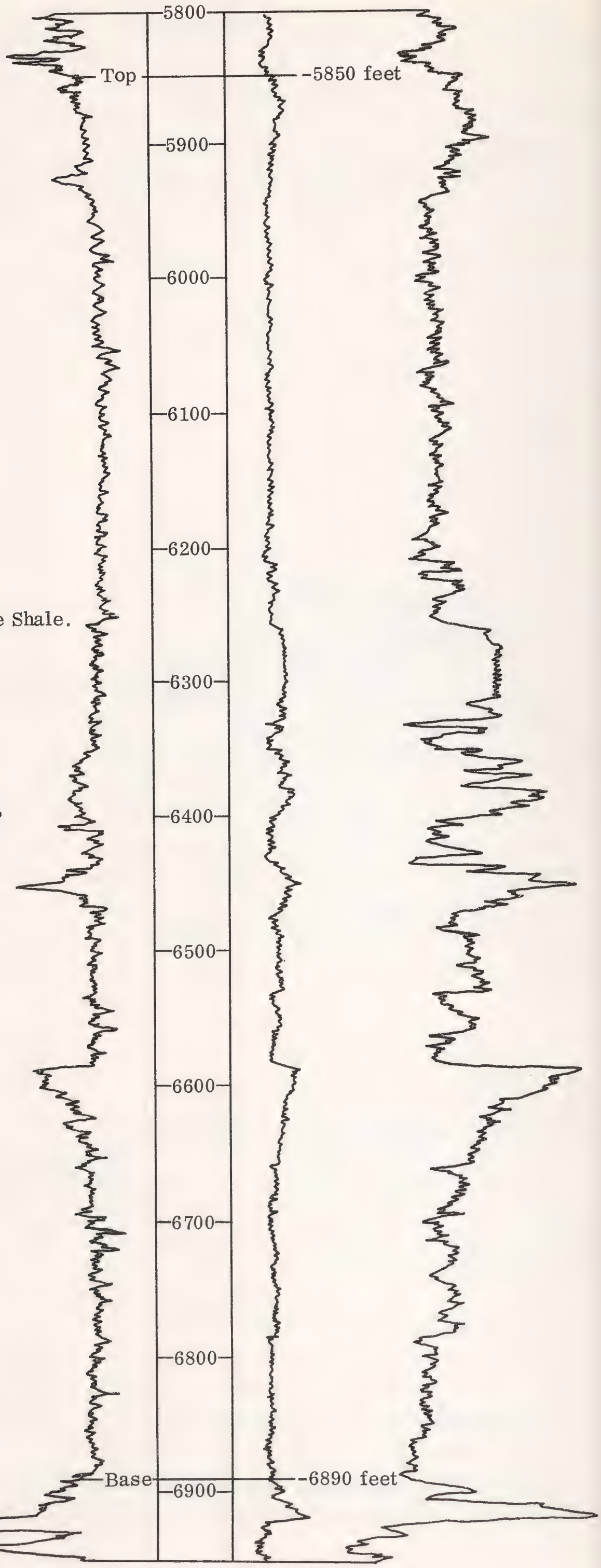


Figure 3. Type Log of the Terrebonne Shale.

-5850 to -6890 feet

Gulf Refining Company
#A-1 OCS 0498
Block 128
South Timbalier Area
(Block 135 Field)
Offshore Terrebonne Parish,
Louisiana Continental Shelf

AGE OF SAMPLES	LATE PLIOCENE			EARLY PLEISTOCENE Terrebonne Shale																				
LOCATION OF SIDEWALL CORES	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Acanthoica sp.													R											
Braarudosphaera bigelowi		R				R					R					R						R		
Calyptrosphaera oblonga										R														
Ceratolithus cristatus			R		R	R		R		R			R				S			S		R	R
Ceratolithus rugosus	S	R	R	R	R																			
Coccolithus doronicoides	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Coccolithus pelagicus	R		R		R	R								R										
Coccolithus productus		R	S		R	S		R			S					R			S			S		
Cricolithus jonesi	R					R			S				R						R					
Cristallolithus macroporus										R											R			
Cyclococcolithina leptopora	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Cyclococcolithina macintyrei	C	C	C	C	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Discoaster brouweri	C	C	S	R		S																		
Discolithina anisotrema	S	R	S	S	S	S			S		R			S	S		S		R			R		
Discolithina japonica		R			R	R			R		R						R					R		
Emiliania annula				R						R		R		S	S					S		S	S	
Gephyrocapsa aperta										R						R							R	
Gephyrocapsa caribbeanica						R	R	S	S	S	S	S	C	C	A	A	A	A	A	A	A	A	A	A
Gephyrocapsa protohuxleyi													R											
Helicopontosphaera cf. H. intermedia			R									R							R					
Helicopontosphaera kamptneri	S	S	S	S	S	S	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Homozygosphaera wettsteni	S	S	S	S					R								R							
Pseudoemiliania lacunosa	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Rhabdosphaera clavigera	S	S	S	S		S	C	C	S	C	S	S	C	C	S	S	S	S	S	S	S	S	S	S
Scapholithus fossilis	R		R		R	R		S			S		R			R		R		S		S		
Scyphosphaera apsteini	R		R		R				R								R							
Scyphosphaera pulcherrima		R		R			R							R		R					R			
Syracosphaera histrica			R									R					R	R					R	
Syracosphaera pulchra		R			R			R					R							R		R		
Thoracosphaera saxea	C	S	S	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Thoracosphaera sp.							R							S										
Umbilicosphaera mirabilis	C	S	C	S	S	S	C	S	S	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C

Figure 4. Distribution of calcareous nannofossils in late Pliocene-early Pleistocene sediments on the Louisiana Continental Shelf. A – Abundant (500+); C – Common (50-500); S – Scarce (5-50); R – Rare (1-5).

in the wells studied. The cores from the three wells selected were combined into a composite section. The spontaneous potential (SP) curve from one Induction-Electrical Log was selected to illustrate the configuration of the SP curve through the early Pleistocene sediments and the position of each core is marked adjacent to this curve on Figure 6. No log is available for the fourth well which is located in Ship Shoal Block 307.

In addition to the 23 sidewall cores from the Louisiana Continental Shelf, samples were examined from piston cores taken in the Atlantic and Pacific oceans and the distribution of pertinent calcareous nannofossils in these samples was compared with the studied section (see Figure 5). The samples examined from the Atlantic Ocean were from core V10-91 (Lamont), taken 1400 miles east-northeast of San Juan, Puerto Rico, and the JOIDES Blake Plateau cores, located offshore from the east coast of Florida. The samples from the Pacific Ocean were from CAP 38 BP (Scripps), cored 1300 miles east-southeast of the Marquesas Islands.

VII. CALCAREOUS NANNOFOSSILS

The Terrebonne Shale yielded 32 species of nannofossils assignable to 20 genera (see figure 4); the following 19 species are long-ranging forms which occur in sediments older and younger than the studied section or are so rare that they are considered to be of

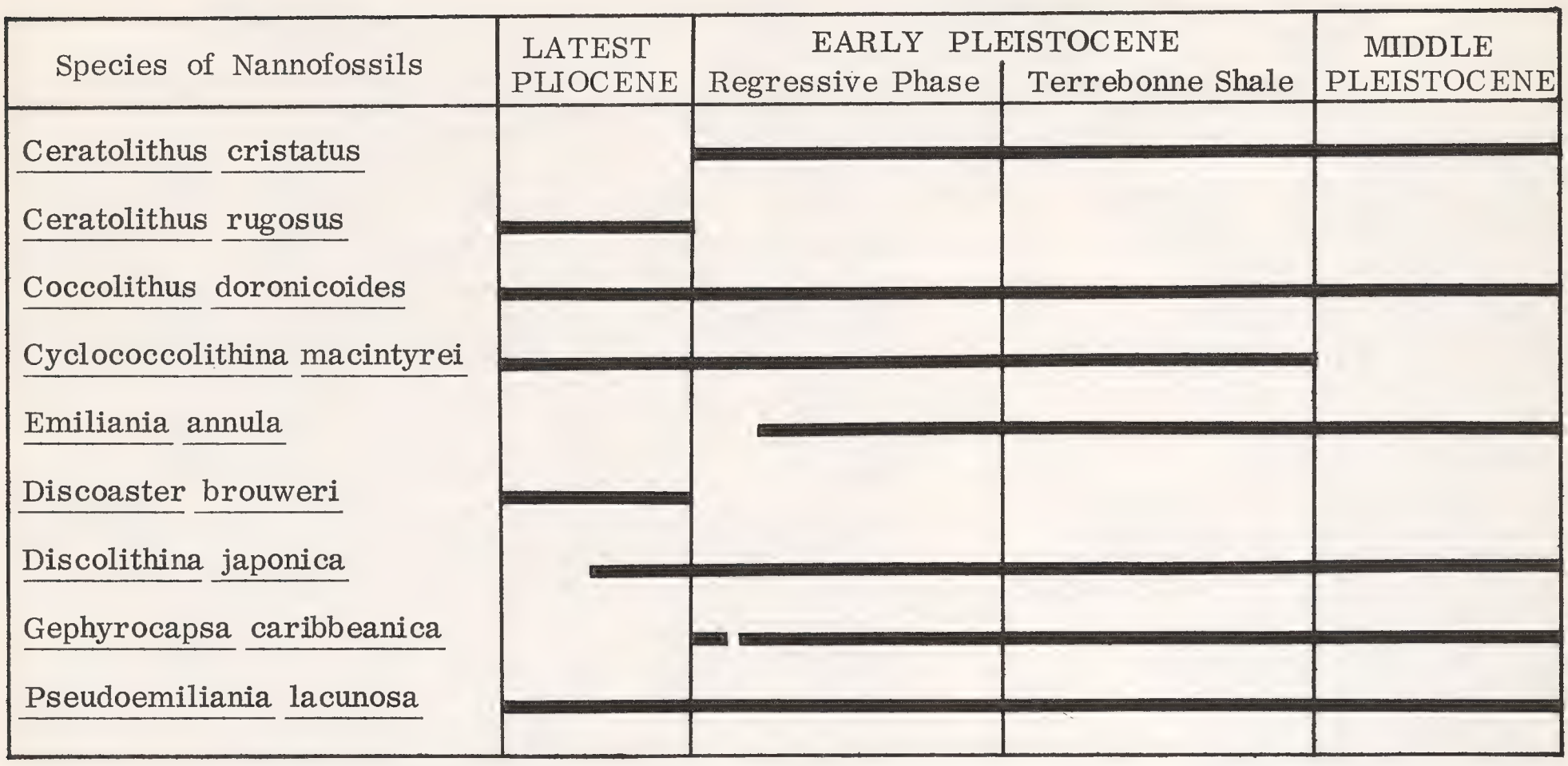


Figure 5. Composite range chart of stratigraphically significant calcareous nannofossils from the latest Pliocene-middle Pleistocene on the Louisiana Continental Shelf.

little value in determining the age of the studied section:

Acathoica sp.
Braarudosphaera bigelowi (Gran and Braarud)
Calyptrosphaera oblonga Lohmann
Cricolithus jonesi Cohen
Cristallolithus macroporus (Deflandre), n. comb.
Cyclococcolithina leptopora (Murray and Blackman)
Discolithina anisotrema (Kamptner)
Helicopontosphaera cf. *H. intermedia* Martini
Helicopontosphaera kamptneri Hay and Mohler
Homozygosphaera wettsteni (Kamptner)
Rhabdosphaera clavigera Murray and Blackman
Scapholithus fossilis Deflandre
Scyphosphaera apsteini Lohmann
Scyphosphaera pulcherrima Deflandre
Syracosphaera histrica Kamptner
Syracosphaera pulchra Lohmann
Thoracosphaera saxea Stradner
Thoracosphaera sp.
Umbilicosphaera mirabilis Lohmann

Two of the recorded species were reassigned to other existing genera:

Coccolithus productus (Kamptner), n. comb.
Cristallolithus macroporus (Deflandre), n. comb.

The following two species have not been reported previously from strata as old as early Pleistocene:

Gephyrocapsa protohuxleyi McIntyre
Cricolithus jonesi Cohen

Two living species are reported herein from the fossil record for the first time:

Homozygosphaera wettsteni (Kamptner)
Calyptrosphaera oblonga Lohmann

The Pleistocene species *Ceratolithus cristatus* (Kamptner) and the Pliocene species *Ceratolithus rugosus* Bukry and Bramlette occur together in the latest Pliocene sediments on the Louisiana Continental Shelf (see figures 4 and 5). However, both species were recorded as rare (less than five specimens per traverse) and cannot be used as definitive evidence for separating Pliocene from Pleistocene strata in this area.

Coccolithus pelagicus has been noted by several workers as temporarily disappearing at or slightly above the horizon that discoasters become extinct. This has been interpreted as indicating the onset of a warming trend. *Coccolithus pelagicus* is rare to scarce in the area studied and in all probability the waters of the Gulf were not cool enough to permit the species to flourish.

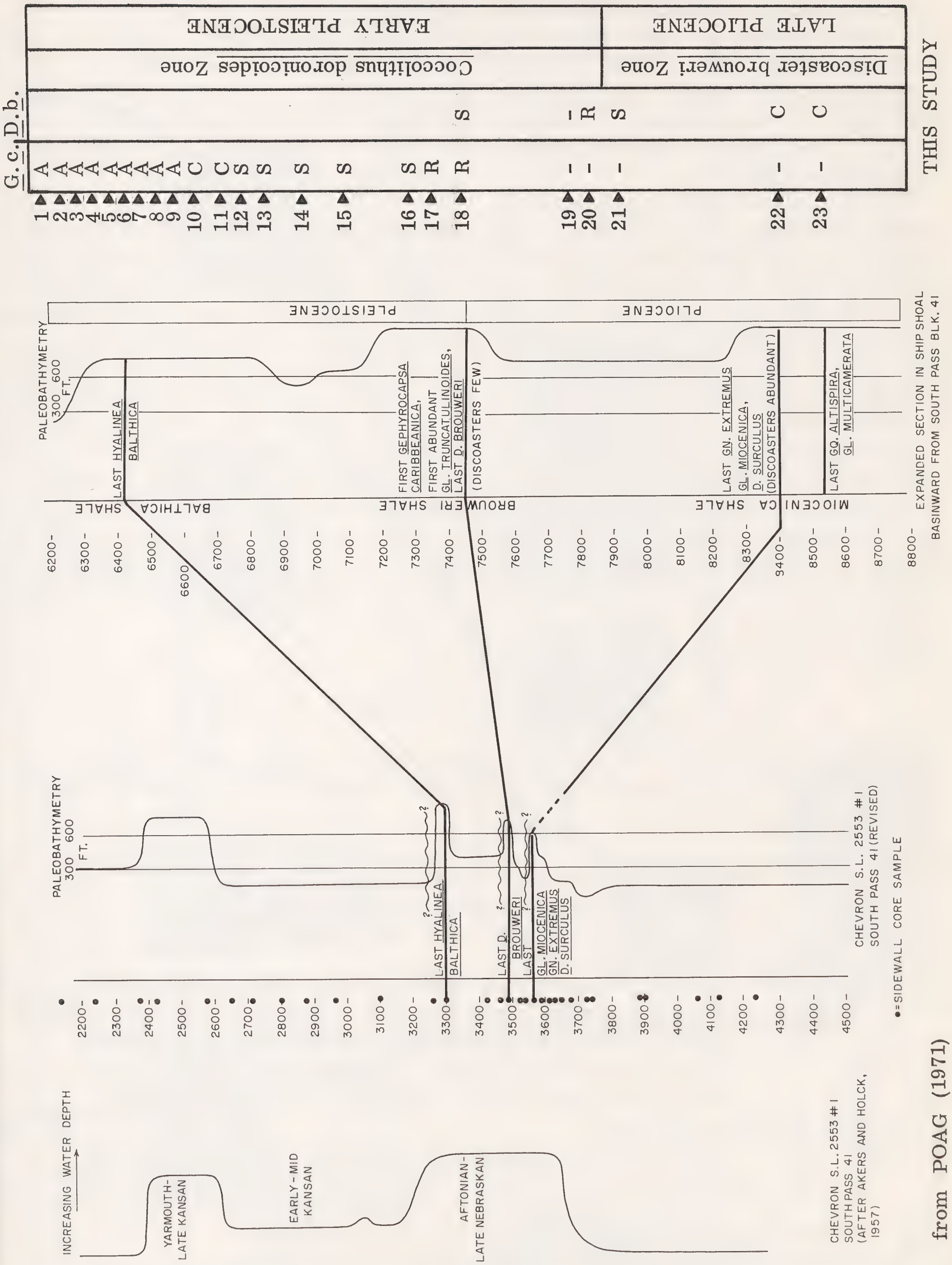

THIS STUDY
LATE PLIOCENE
EARLY PLEISTOCENE
Discoaster brouweri Zone
Coccolithus doronicoides Zone
G. c. D. b.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
A A A A A A A A C C S S S S S R R - - - - - C C
PLIOCENE
PLEISTOCENE
PALEOBATHYMETRY
300 600
FT.
LAST HYALINEA
BALTHICA
FIRST GEPHYROCAPSA CARIBBEANICA,
FIRST ABUNDANT GL. TRUNCATULINOIDES,
LAST D. BROUWERI
(DISCOASTERS FEW)
LAST GN. EXTREMUS
GL. MIOCENICA,
D. SURCULUS
(DISCOASTERS ABUNDANT)
LAST GQ. ALTISPIRA,
GL. MULTICAMERATA
BALTHICA SHALE
BROUWERI SHALE
MIOCENICA SHALE
6200 6300 6400 6500 6600 6700 6800 6900 7000 7100 7200 7300 7400 7500 7600 7700 7800 7900 8000 8100 8200 8300 9400 8500 8600 8700 8800
EXPANDED SECTION IN SHIP SHOAL BLK. 41
BASINWARD FROM SOUTH PASS BLK. 41
PALEOBATHYMETRY
300 600
FT.
LAST HYALINEA
BALTHICA
LAST D. BROUWERI
LAST
GL. MIOCENICA
GN. EXTREMUS
D. SURCULUS
CHEVRON S.L. 2553 #1
SOUTH PASS 41 (REVISED)
•=SIDEWALL CORE SAMPLE
2200 2300 2400 2500 2600 2700 2800 2900 3000 3100 3200 3300 3400 3500 3600 3700 3800 3900 4000 4100 4200 4300 4400 4500
INCREASING WATER DEPTH
YARMOUTH-LATE KANSAN
EARLY-MID KANSAN
AFTONIAN-LATE NEBRASKAN
CHEVRON S.L. 2553 #1
SOUTH PASS 41
(AFTER AKERS AND HOLCK, 1957)
from POAG (1971)

Figure 6. Pliocene-Pleistocene sequence in sediments on the Louisiana Continental Shelf. The frequency distributions of *Gephyrocapsa caribbeanica* and *Discoaster brouweri* are as reported in this study (light microscope). A – Abundant (500+); C – Common (50-500); S – Scarce (5-50); R – Rare (1-5).

Takayama (1967) first reported the species *Discolithina japonica* from the Pleistocene and Pliocene strata of Japan. Bandy and Wilcoxon (1970) also noted a similar distribution of this species in the Calabrian stratotype. On the Louisiana Continental Shelf, rare specimens are found throughout the section (see figure 4).

The *Emiliania annula* subzone (see table 1) erected by Bukry (1971b) is not readily apparent in the studied section although scarce specimens are found in the upper portion of the Terrebonne Shale and rare specimens occur in the lower part of the shale and in the underlying regressive Pleistocene beds (figure 5). None were encountered in the Pliocene section.

Cyclococcolithina macintyrei is common in the late Pliocene sediments of the Louisiana Continental Shelf and scarce throughout the early Pleistocene section. The common occurrence coincides with Bukry's uppermost Pliocene subzone *Cyclococcolithina macintyrei.*

Coccolithus doronicoides Black and Barnes and *Pseudoemiliania lacunosa* Gartner are the most abundant coccoliths in the studied section, together constituting more than one-half of the assemblage. In the upper portion of the Terrebonne Shale, both species decrease in abundance as *Gephyrocapsa caribbeanica* increases (see figures 4 and 5). This relationship was observed first by McIntyre, Bé, and Preikstas (1967) and has since been noted by other workers on cores from both temperate and tropical sediments.

The results of the present study reveal a morphological relationship between *Coccolithus doronicoides* Black and Barnes, *Coccolithus productus* (Kamptner), *Emiliania huxleyi* (Lohmann), *Pseudoemiliania lacunosa* Gartner, and species of the genus *Gephyrocapsa.* It appears that these species are members of a phylogenetic series extending from *Coccolithus doronicoides* in the middle Pliocene to *Emiliania huxleyi* in the Holocene (see Table 2). Morphological changes in this series include:

DESCRIPTION OF TABLE 2

Suggested phylogenetic relationships of *Coccolithus doronicoides, Pseudoemiliania lacunosa, Gephyrocapsa protohuxleyi, Gephyrocapsa caribbeanica, Coccolithus productus,* and *Emiliania huxleyi.*

Figure

1, 2 *Coccolithus doronicoides* Black and Barnes
1. Electron micrograph, distal view, Sigsbee knolls
2. Electron micrograph, proximal view, Sigsbee knolls

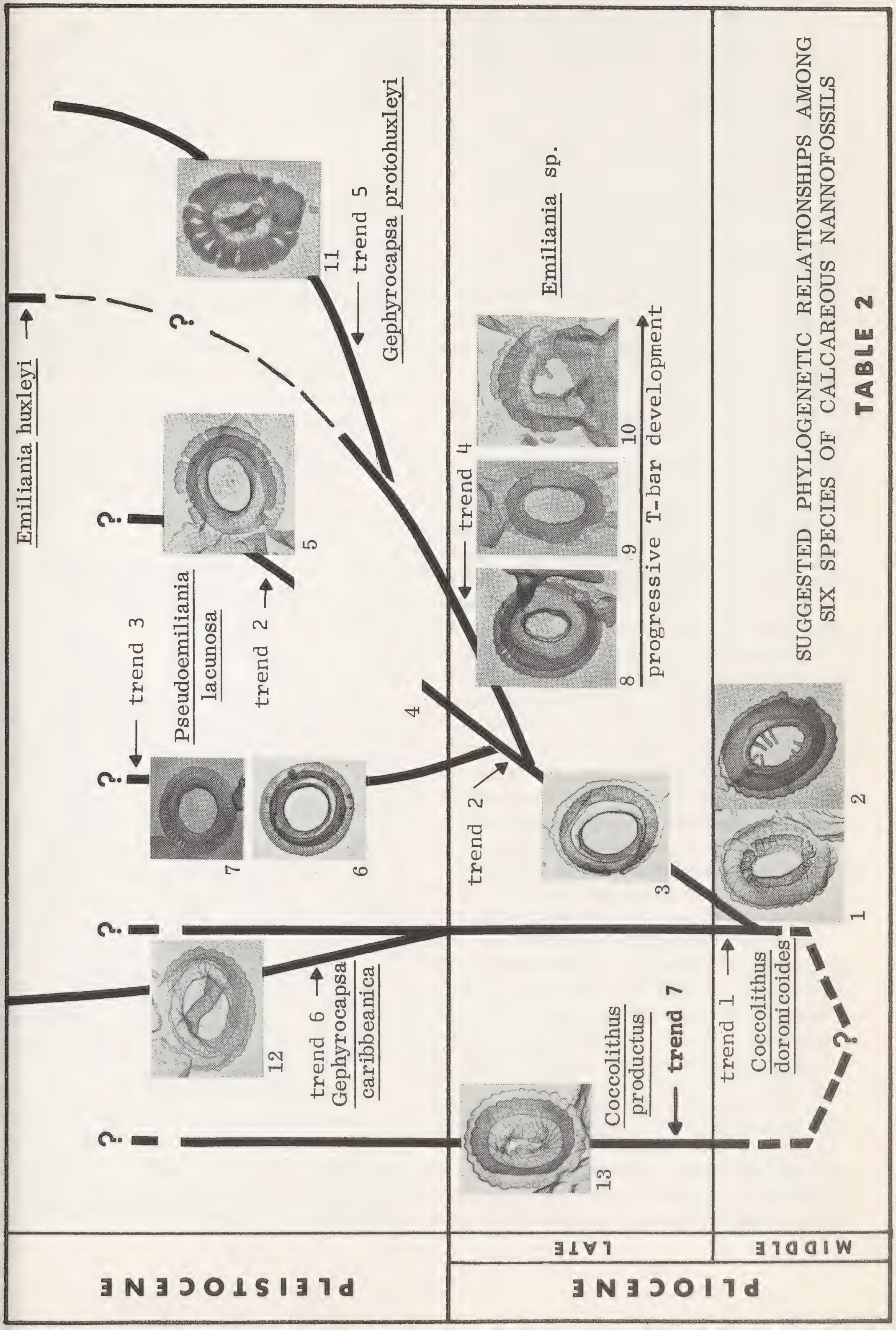
3–7 *Pseudoemiliania lacunosa* Gartner
3. Electron micrograph, proximal view, variant No. 1, Sigsbee knolls
4. Electron micrograph, pronimal view, variant No. 1, Terrebonne Shale
5. Electron micrograph, proximal view, variant No. 1, Sigsbee knolls
6. Electron micrograph, proximal view, variant No. 2, Sigsbee knolls
7. Electron micrograph, distal view, variant No. 2, Sigsbee knolls

8–10 *Emiliania* sp. not designated
8. Electron micrograph, proximal view, variant No. 3, Sigsbee knolls
9. Electron micrograph, proximal view, variant No. 3, Sigsbee knolls
10. Electron micrograph, proximal view, variant No. 3, Terrebonne Shale

11 *Gephyrocapsa protohuxleyi* McIntyre
11. Electron micrograph, distal view, Terrebonne Shale

12 *Gephyrocapsa caribbeanica* Boudreaux and Hay
12. Electron micrograph, proximal view, Terrebonne Shale

13 *Coccolithus productus* (Kamptner), new combination
13. Electron micrograph, proximal view, Sigsbee knolls



SUGGESTED PHYLOGENETIC RELATIONSHIPS AMONG SIX SPECIES OF CALCAREOUS NANNOFOSSILS

TABLE 2

1) reduction of the elliptical central perforation to an irregular, elongated fissure (table 2, figure 13, *Coccolithus productus);*
2) development of slits between adjoining elements on the distal shield, an increase in the size of the central perforation, and the number of elements in both shields (table 2, figures 3–5, *Pseudoemiliania lacunosa);*
3) change to circular shape of the form and its central perforation (table 2, figures 6–7, *Pseudoemiliania lacunosa);* and,
4) development of T-bars on the distal shield (table 2, figure 11, *Gephyrocapsa protohuxleyi).*

Members of this series constitute approximately 60 per cent of the placoliths recovered from the upper Pliocene and lower Pleistocene sediments.

The results of Poag (1971) and those from this study agree with reference to *Gephyrocapsa caribbeanica* (see figure 6). The specimens belonging to this species in cores 17 and 18 were diminutive and in the present study were identified only because we were searching carefully for the first appearance of this important species. Ordinarily, such an occurrence probably would be overlooked. From a pragmatic point of view, the first appearance of *Gephyrocapsa caribbeanica* does take place in core 16. However, interpretation of the upper limit of the distribution of discoasters is the principal point of difference. During the examination of samples from cores 22 and 23 more than 100 discoasters were counted in each traverse. Practically all of these specimens belong to the species *Discoaster brouweri* with rare occurrences (less than five specimens per traverse) of *Discoaster pentaradiatus,* and *Discoaster surculus.* The specimens of these latter two species are considered as being reworked and, thus, are not included in the master list of species. In core 21, about 35 specimens of *Discoaster brouweri* were encountered; in core 20, less than five specimens; in core 19, none were encountered although the sample does contain an abundant flora. The slight increase in discoasters noted in core 18 [most specimens were broken] is attributed to reworking, as this section represents the base of the transgressive depositional phase. In the present study, the top of the *Discoaster brouweri* zone is placed between cores 20 and 21 (which are spaced 40 feet apart) based on the reduction in number of *Discoaster brouweri* recorded. Thus, the difference between the top of the Pliocene as reported by Poag (1971) and in the present study amounts to 500 feet of stratigraphic separation. Examination by the writers of equivalent sections in deep-sea cores from the Atlantic and Pacific oceans failed to reveal a "zone" in which neither discoasters nor *Gephyrocapsa caribbeanica* are encountered such as that seen in cores 17 through 19. This is explained readily by:

1) the characteristic "compressed" nature of deep-sea cores; and,
2) vertical reworking which in deep-sea cores may range from ten to thirty centimeters (McIntyre *et al.,* 1967; Gartner, 1972).

The thick, downdip upper Neogene deposits of the Louisiana Gulf Coast section represent an unique opportunity to study the stratigraphic distribution of calcareous planktonic assemblages in an undistorted sequence. In most areas, the natural process of reworking of the sediments produces troublesome anomalies in the ranges of calcareous nannofossils. Such is the case with the ranges of *Discoaster brouweri* and *Gephyrocapsa caribbeanica* as reported by other authors, especially those working with deep-sea cores. In the greatly thickened strata of the Gulf Coast province Neogene, these anomalies are significantly reduced by the "expanded" nature of the section. In the present study, the frequency distribution of both species, *Discoaster brouweri* and *Gephyrocapsa caribbeanica,* is emended and compared with previously published distributions and ranges (see figure 6).

VIII. CONCLUSIONS

Biostratigraphers interested in late Neogene zonation are faced with a most perplexing problem. With the countless investigations that have been initiated to study the Pliocene-Pleistocene boundary

problem, it seems incredible that there is no single definitive, illustrated study of a major micropaleontologic group from the Calabrian at Santa Maria di Catanzaro, the stratotype section, or the purported equivalent section at Le Castella, some twenty-five miles to the east of Catanzaro.

In consideration of the studies by Bayliss (1969), Lamb (1969), and Bandy and Wilcoxon (1970) of the type Calabrian and pre-Calabrian sediments at Santa Maria di Catanzaro, all of which report the first appearance of *Globorotalia truncatulinoides* at different levels near the top of the section, and none of which report this species in abundance at the stratotype or at Le Castella, it seems questionable whether *Globorotalia truncatulinoides* can be utilized at this time as a meaningful basis for delineating the Pliocene-Pleistocene boundary. Considering that no consensus on definition of this boundary has yet been reached by the Committee on Mediterranean Neogene Stratigraphy, and that considerable doubt remains on the usefulness of *Globorotalia truncatulinoides* for any purpose other than as a guide to the early Pleistocene, the question of whether the base of the Pleistocene can be recognized utilizing planktonic Foraminiferida is still open.

The distribution of calcareous nannofossils at the stratotype as reported by Smith (1969) and by Bandy and Wilcoxon (1970) are in direct conflict. Smith reported discoasters extending throughout the Calabrian section and that *Gephyrocapsa caribbeanica* was absent. The distribution of coccoliths as reported by Smith is difficult to interpret as resolution of the taxonomic differences involving late Neogene forms was then in a preliminary stage. Bandy and Wilcoxon restricted their investigation to the presence or absence of the discoasters *Gephyrocapsa caribbeanica, Pseudoemiliania lacunosa,* and *Discolithina japonica* and concluded that discoasters became extinct at the base of the Pleistocene; they also recorded the presence of *Gephyrocapsa caribbeanica* in the Calabrian and in the one sample they examined from the top of the underlying Pliocene. No frequency distribution was reported by Bandy and Wilcoxon. In neither of the studies were any specimens figured, although Smith reported on the frequency of major generic groups. It appears that these important differences cannot be reconciled.

It remains quite clear that definitive criteria (based on any major group of microfossils) suitable for recognition of the Pliocene-Pleistocene boundary are not now available due to the lack of comprehensive and illustrated studies of microfossils from the stratotype section. Thus, it is impossible to propose criteria acceptable to a significant number of biostratigraphers interested in this problem. Until proper definitive and detailed studies are made of both planktonic Foraminiferida and calcareous nannofossils at the stratotype section at Santa Maria de Catanzaro and of the Calabrian section at Le Castella this problem cannot be resolved. Therefore, lacking alternatives, the customary procedure of delineating the Pliocene-Pleistocene boundary based on the extinction of *Discoaster brouweri* and on the approximate first appearance of *Gephyrocapsa caribbeanica* is followed in this study.

Thirty-two species of calcareous nannofossils from 20 genera were identified from the late Pliocene and early Pleistocene strata of the Louisiana Continental Shelf. Of these 32 species, two are sufficiently restricted to be useful stratigraphically. These two species aid in defining the base of the Terrebonne Shale which is named herein. The calcareous nannofossils which define this horizon are:

1) the extinction of *Discoaster brouweri* Tan Sin Hok; and,
2) the first appearance of *Gephyrocapsa caribbeanica* Boudreaux and Hay.

This interface is recognized also in samples from core V10-91 (Lamont) from the Atlantic Ocean, from CAP 38 BP (Scripps) from the Pacific Ocean, and in cores from the Blake Plateau. This stratigraphic level is of major correlative importance.

The following additional results were obtained from this study:

1) A phylogenetic series extending from *Coccolithus doronicoides* Black and Barnes, in the middle Pliocene section

to *Emiliania huxleyi* (Lohmann) in the Holocene has been recognized and delineated;

2) this series reveals a morphological relationship among the following species:

Coccolithus doronicoides Black and Barnes
Coccolithus productus (Kamptner)
Emiliania huxleyi (Lohmann)
Pseudoemiliania lacunosa Gartner
Gephyrocapsa caribbeanica Boudreaux and Hay
Gephyrocapsa protohuxleyi McIntyre;

3) *Ceratolithus cristatus* Kamptner) and *Ceratholithus rugosus* Bukry and Bramlette occur together in the earliest Pleistocene sediments, confirming the distribution of these species as reported by other authors;

4) the geologic ranges of two species, *Gephyrocapsa protohuxleyi* McIntyre and *Cricolithus jonesi* Cohen, are extended back to the early Pleistocene;

5) two species, *Homozygosphaera wettsteni* (Kamptner) and *Calyptrosphaera oblonga* Lohmann, are first reported from the fossil record; and,

6) two species, *Coccolithus productus* (Kamptner), n. comb., and *Cristallolithus macroporus* (Deflandre), n. comb., are reassigned to other existing genera.

IX. ACKNOWLEDGMENTS

The writers are deeply indebted to several colleagues who have contributed substantially to the research reported here. Among these are W. H. Akers, who provided counsel and encouragement throughout the study; Stefan Gartner, Jr., who provided extensive technical advice, counsel, and help throughout the work; and Harold E. Vokes who assisted with stratigraphic problems. These three men also served as members of the editorial committee. We are grateful to Cesare Emiliani, W. W. Hay, C. Wylie Poag, and Ruth Trencher for technical advice, assistance, and making available much needed equipment and facilities.

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X. SYSTEMATIC PALEONTOLOGY

Kingdom PROTISTA
Phylum CHRYSOPHYTA
Class COCCOLITHOPHYCEAE Rothmaler
Order COCCOLITHALES
Family COCCOLITHACEAE Kamptner, 1928

Genus COCCOLITHUS Schwarz, 1894

Type species: *Coccolithus oceanicus* Schwarz, 1894.

Definition: Elliptical placoliths, the smaller or proximal shield and the larger or distal shield are connected by a central tube or collar. Both shields are curved, with the concave surface on the proximal side and the convex surface on the distal side.

COCCOLITHUS DORONICOIDES
Black and Barnes
Table 2, figs. 1, 2;
Plate 1, figs. 1, 2, 6–8

Coccolithus doronicoides BLACK and BARNES, 1961, Roy. Micros. Soc., Jour., ser. 3, Vol. 80, pt. 2, p. 142, pl. 25, fig. 3.

Ellipsoplacolithus galenis KAMPTNER, 1967, Naturh. Mus. Wien, Ann., vol. 71, p. 140, pl. 6, fig. 41.

Coccolithus doronicoides Black and Barnes. McINTYRE, BÉ, and PREIKSTAS, 1967, Progress in Oceanography, vol. 4, p. 8, pl. 2, figs. A, B.

Coccolithus doronicoides Black and Barnes. COHEN and REINHARDT, 1968, Neues Jahrb. Geologie Paläontologie, Abh., vol. 131, no. 3, p. 239, pl. 20, fig. 4.

Description: "Coccoliths consisting of two broadly elliptical or almost circular shields, nearly equal in size, with a large central opening approximately one-third the diameter of the smaller shield. Rays of the two shields are equal in number, narrow, gently curved and bluntly pointed; adjacent rays are separated by a suture at right angles to the surface of the shield and are never overlapping." (Black and Barnes, 1961)

Discussion: Commenting on their original description, Black and Barnes (1961) state that in all observed specimens the central pore is either obscured or damaged and that they are uncertain if the pore is in fact large, with the possibility that the pore of a complete undamaged specimen would possess a fine grill.

The holotype contains 37 elements in each shield but, as the authors state, the other 8 specimens they examined are constructed of from 28 to 48 elements and it is probable that more than one species is included among their material.

McIntyre, Bé, and Preikstas (1967) redescribed *Coccolithus doronicoides,* and broadened the definition of this species, differing on several points from Black and Barnes. McIntyre *et al.* (1967) state that the distal shield possesses a strongly developed ring surrounding the central pore (Table 2, fig. 1) and that "this ring of elements is sinistrally imbricate and is separated by a channel from the dextrally imbricated outer elements, which are occasionally incomplete. The elements of the proximal shield are sinistrally imbricate. The suture lines are radial throughout most of the shield width, both distally and proximally." The element count reported by McIntyre *et al.* also differs in that they recognized an elliptical form of 40 to 50 elements with a mean of 48, and a circular variant with an element count of 50 to 68, and a mean of 63 elements. Thus, they agree with Black and Barnes that more than one species is involved.

Coccolithus doronicoides and *Pseudoemiliania lacunosa* are the dominant coccoliths in the section studied where they constitute more than one-half of the assemblage. *Coccolithus doronicoides* is believed to be a progenitor of *Emiliania huxleyi* (Lohmann), the most ubiquitous coccolith in the modern oceans, and to be ancestral to the genus *Gephyrocapsa,* another major group of placoliths.

Studies of the late Pliocene and early Pleistocene sediments from the Louisiana Continental Shelf with the aid of light and electron microscopes have revealed several evolutionary trends among placoliths from this area which are discussed below and figured in Table 2.

Trend No. 1: The elliptical form known as *Coccolithus doronicoides* first appears in middle Pliocene beds and continues to be present higher in the section, increasing in abundance until it constitutes a significant percentage of the placoliths in late Pliocene and early Pleistocene sediments (see Table 2, figs. 1, 2; Plate 1, figs. 1, 2, 6–8). It is this elliptical form that Black and Barnes (1961) designated as the type of *Coccolithus doronicoides.*

In 1967, Kamptner proposed a new species *Ellipsoplacolithus galenis* for a form very similar to *Coccolithus doronicoides* but with 30 elements as compared to 37 in the holotype of *Coccolithus doronicoides.* However, this is well within the range of variation noted by Black and Barnes, and *Ellipsoplacolithus galenis* is considered a junior synonym of *Coccolithus doronicoides.*

Trend No. 2: In middle Pliocene, certain forms derived from *Coccolithus doronicoides* developed slits between the adjoining elements on the distal shield with an increase in the number of elements in both shields and the distal collar. This new form, which retains the elliptical shape of its ancestor, has been designated *Pseudoemiliania lacunosa* by Gartner (1969). *Pseudoemiliania lacunosa* became extinct within the middle Pleistocene (see Table 2, figs. 3–7; Plate 1, figs. 3–5, 9–13).

Trend No. 3: From trend No. 2 another variation developed in the middle or late Pliocene. The form and the central perforation are circular and the latter increases in size at the expense of the width of the shields (see Table 2, figs. 6, 7; Plate 1, figs. 12, 13). As this variant became extinct at approximately the same level as *Pseudoemiliania lacunosa,* it is assigned provisionally to this species.

Trend No. 4: Another distinctive elliptical variant is produced when the slits on the distal shield become enlarged and the remaining elements develop into distinctive T-bars (see Table 2, figs. 8, 9, 10; Plate 2, fig. 10). The results of the present study reveal that this form may be ancestral to both *Gephyrocapsa*

protohuxleyi and *Emiliania huxleyi,* although a gap in the known geologic record exists between this variant and the first appearance of *Emiliania huxleyi. Gephyrocapsa protohuxleyi* may be derived from the T-bar variant form by addition of the characteristic *Gephyrocapsa* bridge, and *Emiliania huxleyi* may have been derived from this same variant by addition of a second series of T-bars on the proximal shield. The T-bar variant form from trend No. 4 is here placed in the genus *Emiliania* but is not assigned to a nominal species pending further study of more definitive material.

Trend No. 5: Specimens in trend No. 5 differ from those in trend No. 4 by the addition of a bridge across the central pore (see Table 2, fig. 5; Plate 2, fig. 11). This form has been designated *Gephyrocapsa protohuxleyi* by McIntyre (1970), and is, according to its author, the ancestor of *Emiliania huxleyi.* If McIntyre is correct, this represents a reversal in evolution as *Emiliania huxleyi* does not possess a bridge. It appears much more logical that *Emiliania huxleyi* developed from the T-bar variant (see discussion above) without the necessity of first developing and then losing a bridge.

PLATE 1

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	2. Electron photomicrograph, oblique view, X 12,750	
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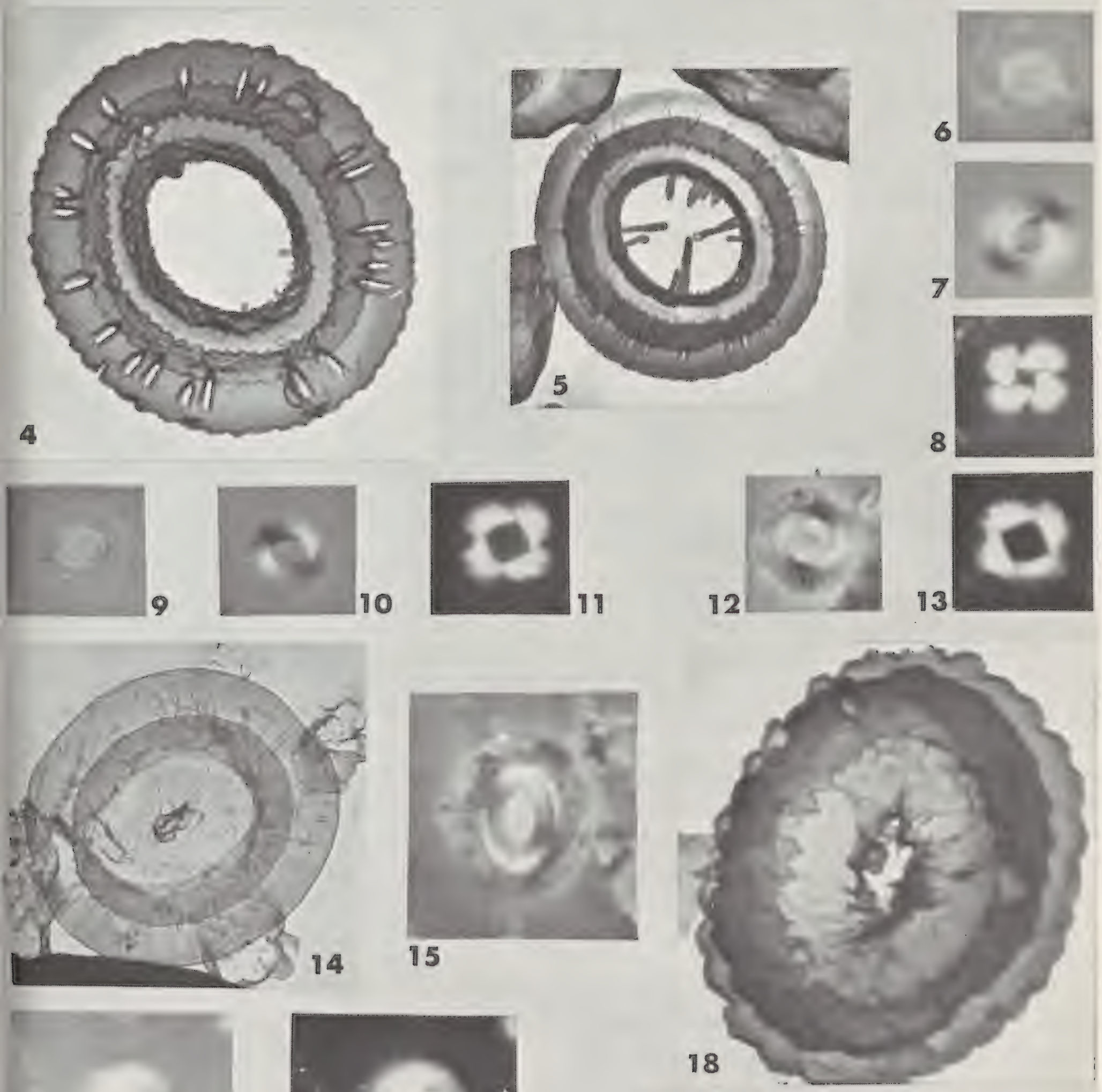

PLATE 1

Trend No. 6: Gephyrocapsa caribbeanica, a small placolith, is derived from the small, elliptical *Coccolithus doronicoides* by addition of a bridge during the early Pleistocene (see Table 2, fig. 12; Plate 2, figs. 1–8). McIntyre, Bé, and Preikstas (1967) in discussing *Coccolithus doronicoides* and comparing this species to diminutive specimens of the genus *Gephyrocapsa,* state that "if the bridge were lost it would be impossible to tell them apart."

Trend No. 7: In certain late Pliocene placoliths, the central pore is reduced to an elongated, irregular fissure; this form is here designated *Coccolithus productus,* n. comb. (see discussion of *Coccolithus productus* and Table 2, fig. 13).

Reported occurrences: Middle Pliocene to middle Pleistocene.

COCCOLITHUS PELAGICUS
(Wallich)
Plate 1, figs. 14–17

Coccosphaera pelagica WALLICH, 1877, Ann. Mag. Nat. Hist., ser. 4, vol. 19, p. 348, pl. 17, figs. 1, 2, 5, 11, 12.

Coccolithus pelagicus (Wallich). SCHILLER, 1930, *in* L. RABENHORST, Kryptogamen-Flora, Leipzig, vol. 10, p. 246.

Coccolithus pelagicus (Wallich) Schiller. KAMPTNER, 1954. Archiv. Protistenk., vol. 100, p. 20, 21, figs. 14, 15.

Coccolithus pelagicus (Wallich). COHEN, 1965, Leidsche Geologische Mededelingen, vol. 35, p. 11, pl. 1, figs. a–c.

Coccolithus pelagicus (Wallich) Schiller. McINTYRE, BÉ, and PREIKSTAS, 1967, Progress in Oceanography, vol. 4, p. 11, figs. A, B.

Coccolithus pelagicus (Wallich) Schiller. McINTYRE and BÉ, 1967, Deep-Sea Research, vol. 14, p. 569, pl. 8, figs. A–C.

Discussion: This large oval placolith, one of the first described coccoliths, is very rare in the Terrebonne Shale. Its scarcity is attributed to its preference for colder waters (McIntyre and Bé, 1967).

Hay and Boudreaux (1968) drew a similar conclusion in their report on the *Submarex* core from the Nicaragua Rise stating that the extinction of *Coccolithus pelagicus* is coincident with the onset of warmer temperatures as determined by Bolli *et al.* (1968).

Reported occurrences: Oligocene to Holocene.

COCCOLITHUS PRODUCTUS
(Kamptner),
new combination
Table 2, fig. 13;
Plate 1, figs. 18–21

Ellipsoplacolithus productus KAMPTNER, 1963, Naturh. Mus. Wien, Ann., vol. 66, p. 172, pl. 8, figs. 42, 44.

Description: Elliptical placolith, 2.7–2.9 microns long and 2.0–2.3 microns wide. The larger convex distal shield consists of 30 to 40 elements which are inclined in one direction; the periphery of the shield is serrated. The proximal shield, which also has a serrated periphery, is concave and contains the same number of elements as the distal shield. The central perforation is narrow, irregular, and elongated (modified from Kamptner, 1963).

Discussion: The character of the central perforation distinguishes this species from *Coccolithus doronicoides,* to which it is probably related (see Table 2, fig. 13) and with which it may be confused. In electron microscope study, where clay or other fine debris may cover portions of the central pore, or if the micrograph is of poor quality (as is Plate 1, fig. 18), the form could be misidentified as *Coccolithus doronicoides.* In cross-polarized light (see Plate 1, fig. 21) the elliptical pore is not visible and the pseudointerference figure is distinctive.

The International Code of Botanical Nomenclature provides that provisional or conditional generic names are invalid (Art. 34, par. i). Thus, *Ellipsoplacolithus* is invalid, but the species-group name *productus* is valid when used in combination with a valid generic name. As the form is similar to *Coccolithus doronicoides,* the species is here reassigned to the genus *Coccolithus.*

Reported occurrences: Pliocene and Pleistocene.

Genus GEPHYROCAPSA
Kamptner, 1943

Type species: *Gephyrocapsa oceanica* Kamptner, 1943.

Definition: Elliptical placoliths with a central pore spanned by a bridge not aligned with the major or minor axes of the ellipse.

GEPHYROCAPSA APERTA
Kamptner
Plate 2, fig. 9

Gephyrocapsa aperta KAMPTNER, 1963, Naturh. Mus. Wien, Ann., 66, p. 173, pl. 6, figs. 32, 35.

Discussion: The large elliptical central perforation and the narrow shields are characteristic of this species. The figured specimen is identical with that of Kamptner (1963). Only one specimen was encountered in the electron microscope work. Because of its diminutive size and rarity, this form is not readily identified with the light microscope.

Reported occurrences: Pleistocene.

GEPHYROCAPSA CARIBBEANICA
Boudreaux and Hay
Table 2, fig. 12;
Plate 2, figs. 1–8

Gephyrocapsa caribbeanica BOUDREAUX and HAY, 1967, *in* HAY *et al.,* Gulf Coast Assoc. Geol. Soc., Trans., vol. XVII, p. 447, pl. 12, figs. 1–4; pl. 13, figs. 1–4.

Gephyrocapsa caribbeanica Boudreaux and Hay. SMITH, 1969, Gulf Coast Assoc. Geol. Soc., Trans., vol. XIX, p. 579–583, figs. 1–3.

Gephyrocapsa caribbeanica Boudreaux and Hay. GARTNER, 1969, Gulf Coast Assoc. Geol. Soc., Trans., vol. XIX, p. 585–599, figs. 1–7.

Discussion: This placolith is rare at the base of the studied section but becomes increasingly abundant in the upper portion of the Terrebonne Shale where it constitutes about 20 per cent of the calcareous nannofossils. This increase in abundance is at the expense of *Coccolithus doronicoides* and *Pseudoemiliania lacunosa.*

Satisfactory phase and interference contrast pictures are not obtained due to the diminutive size of this form, but the pseudointerference image is distinctive. [The origin of *Gephyrocapsa* has been discussed under *Coccolithus doronicoides.*]

Reported occurrences: An important but unresolved conflict exists in the distribution of this species as reported by Smith (1969), and Bandy and Wilcoxon (1970). In both papers, *Gephyrocapsa caribbeanica* was reported from Le Castella, but only Bandy and Wilcoxon recorded the species at the Calabrian stratotype section. Until this difference is reconciled, the problem of the first appearance of *Gephyrocapsa caribbeanica* cannot be resolved. (?) Pliocene to middle Pleistocene.

GEPHYROCAPSA PROTOHUXLEYI
McIntyre
Table 2, fig. 11;
Plate 2, fig. 11

Gephyrocapsa protohuxleyi McINTYRE, 1970, Deep-Sea Research, vol. 17, p. 187–190, fig. 1.

Description: "Placolith, oval in plan view, convex proximally with a large elliptical central pore and a bridge crossing the pore on the distal surface." (McIntyre, 1970). The larger distal shield is constructed of T-bars as in *Emiliania huxleyi;* the smaller proximal shield is constructed of tabular elements, similar to those of *Coccolithus doronicoides.*

Discussion: According to McIntyre,(1970) this species varies considerably with ecologic conditions. In specimens from lower latitudes the T-bars on the distal shield are thickened and fused together at the margin, but the elements on the smaller proximal shield are rounded and partially fused, at a stage of development intermediate between a solid shield and that of the distal shield. In addition, forms from the lower latitudes have a thickened bridge. Identification of this species in the Louisiana Shelf area, with both T-bars and bridge, extends its lower range into the early Pleistocene strata.

Rare forms similar to *Gephyrocapsa protohuxleyi,* but lacking a bridge are also encountered (see Table 2, figs. 9–11) but the data were insufficient to ascertain whether these represent a new species; they are provisionally assigned to *Emiliania* sp.

Reported occurrences: Early Pleistocene to late Pleistocene, Atlantic Ocean and Gulf of Mexico.

Genus PSEUDOEMILIANIA
Gartner, 1969

Type Species: *Ellipsoplacolithus lacunosa* Kamptner, 1963.

Definition: Elliptical to circular placoliths. Shields solid or with radial slits located between adjacent elements. Center open or with grillwork.

PSEUDOEMILIANIA LACUNOSA
(Kamptner)
Table 2, figs. 3–7;
Plate 1, figs. 3–5, 9–13

Ellipsoplacolithus exsectus KAMPTNER, 1963, Naturh. Mus. Wien, Ann., vol. 66, p. 171, pl. 9, figs. 51, 52 [figure 52 is incorrectly labelled].

Ellipsoplacolithus lacunosus KAMPTNER, 1963, Naturh. Mus. Wien, Ann., vol. 66, p. 172, pl. 9, fig. 50.

Coccolithus doronicoides Black (partim). McINTYRE, BÉ, and PREIKSTAS, 1967, Progress in Oceanography, vol. 4, p. 8, pl. 3, fig. A.

Umbilicosphaera cricota (Gartner). COHEN and REINHARDT, 1968, Neues Jahrb. Geologie Paläontologie, Abh., vol. 131, p. 296, pl. 21, fig.3.

Pseudoemiliania lacunosa (Kamptner). GARTNER, 1969, Gulf Coast Assoc. Geol. Soc., Trans., vol. XIX, p. 598, pl. 2, figs. 9, 10.

Discussion: As previously stated, development of slits between adjoining elements on the larger distal shield and increase in the number of elements of both shields differentiates this species from *Coccolithus doronicoides* from which it was derived (see discussion of *Coccolithus*

PLATE 2

Figures		Page
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	2. Electron photomicrograph, distal view, X 11,000	
	3. Phase contrast, X 2250	
	4. Interference contrast, X 2250	
	5. Crossed nicols, X 2250	
	6. Phase contrast, X 2250	
	7. Interference contrast, X 2250	
	8. Crossed nicols, X 2250	
9	*Gephyrocapsa aperta* Kamptner	139
	9. Electron photomicrograph, proximal view, X 15,500	
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11	*Gephyrocapsa protohuxleyi* McIntyre	139
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16, 17	*Cyclococcolithina leptopora* (Murray and Blackman)	142
	16. Electron photomicrograph, proximal view isolated distal shield, var. "B", X 5950	
	17. Electron photomicrograph, proximal view, var. "B", X 5950	

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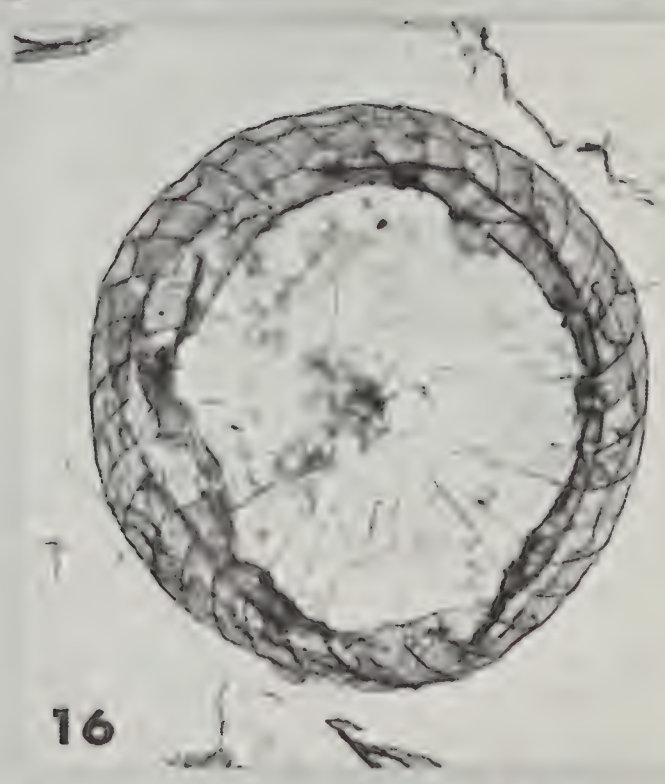
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PLATE 2

doronicoides).

Two varieties occur within the species:

a) an elliptical form (see Table 2, figs. 3–5: Plate 1, figs. 3–5, 9–11); and,

b) a circular form (see Table 2, figs. 6, 7; Plate 1, figs. 12, 13).

In this study the circular form appears to occur first in late Pliocene. Other workers have recorded both forms as becoming extinct at approximately the same horizon in the middle Pleistocene strata. Considering that the extinctions appear to coincide, it does not seem prudent to subdivide or "split" the species.

Reported occurrences: Middle Pliocene to middle Pleistocene.

Genus CYCLOCOCCOLITHINA Wilcoxon, 1970

Type species: *Coccosphæra leptopora* Murray and Blackman, 1898.

Definition: Circular placolith with a larger distal shield and a smaller proximal shield. The shields are attached to each other by a collar or tube.

CYCLOCOCCOLITHINA LEPTOPORA (Murray and Blackman)

Plate 2, figs. 16, 17;
Plate 3, figs. 1–9

Coccosphaera leptopora MURRAY and BLACKMAN, 1898, Roy. Soc. London, Phil. Trans., ser. B., vol. 190, p. 430, pl. 15, figs. 1–7.

Coccolithosphora leptopora (Murray and Blackman). LOHMANN, 1902, Archiv. Protistenk., vol. 1, p. 138, pl. 5, figs. 52, 61–64.

Coccolithus leptoporus (Murray and Blackman). SCHILLER, 1930, *in* L. RABENHORST, Kryptogamen-Flora, vol. 10, p. 245, text-fig. 10.

Coccolithus leptoporus (Murray and Blackman). KAMPTNER, 1941, Naturh. Mus. Wien, Ann., vol. 51, p. 94, pl. 13, figs. 137–139.

Cyclococcolithus leptoporus (Murray and Blackman). KAMPTNER, 1954, Archiv. Protistenk., vol. 100, p. 23, fig. 20.

Coccolithus leptoporus (Murray and Blackman). GARDET, 1955, Publ. Service Carte Géol. Algérie, N.S., Bull. 5, p. 513, pl. 6, fig. 50.

Coccolithus leptoporus (Murray and Blackman). BLACK and BARNES, 1961, Roy. Micros. Soc., Jour., ser. 3, vol. 80, pl. 2, p. 143, pl. 24, figs. 3, 4.

Cyclococcolithus leptoporus (Murray and Blackman). MARTINI and BRAMLETTE, 1963, Jour. Paleontology, vol. 37, no. 4, p. 850, pl. 102, figs. 4, 5.

Cyclococcolithus leptoporus (Murray and Blackman). COHEN, 1964, Micropaleontology, vol. 10, no. 2, p. 237, pl. 1, figs. 6 a–e, pl. 2, figs. h, i; pl. 18, figs. a–e; pl. 19, figs. a, b.

Cyclococcolithus leptoporus (Murray and Blackman) Kamptner. PYLE, 1966, Texas A & M Univ., Dept. Oceanography Tech. Rept. 66–13T, p. 21, pl. 2, fig. 3.

Coccolithus leptoporus (Murray and Blackman). McINTYRE, BÉ, and PREIKSTAS, 1967, Progress in Oceanography, vol. 4, p. 9 (partim), pl. 4, figs. C, D; pl. 5, figs. A, C, D [*not* pl. 2, figs. A, B = *Cyclococcolithina macintyrei*].

Cyclococcolithus leptoporus (Murray and Blackman). McINTYRE and BÉ, 1967, Deep-Sea Research, vol. 14, p. 569, pl. 7, figs. A–C.

Cyclococcolithus leptoporus (Murray and Blackman). GARTNER, 1967a, Univ. Kansas Paleont. Contr., paper 28, p. 1–3, pl. 1, figs. 1–4, pl. 2, figs. 1–4.

Cyclococcolithina leptopora (Murray and Blackman). WILCOXON, 1970, Tulane Stud. Geol. Paleont., vol. 8, no. 2, p. 82.

Discussion: In an investigation of the Pliocene-Pleistocene boundary, McIntyre *et al.* (1967) examined two hundred and thirty-three specimens of *Cyclococcolithina leptopora* and came to the conclusion that three varieties were present (see Table 3).

They stated that nearly three per cent of the specimens do not correspond to the varieties described (see table 3), but because of the polymorphic nature of coccolithophorids, these could not be designated as separate species. However, as indicated by McIntyre *et al.*, the stratigraphic distribution across the Pliocene-Pleistocene boundary shows that their variety "A" [now *Cyclococcolithina macintyrei* (Bukry and Bramlette)] becomes extinct, variety "B" decreases significantly, and variety "C" increases considerably at the boundary.

Cyclococcolithina leptopora is quite common in the studied section and varieties "B" and "C" are present, but because of the terrigenous nature of the sediment the material cannot be analyzed meaningfully in the same way as deep-sea sediments.

Reported occurrences: Miocene to Holocene.

CYCLOCOCCOLITHINA MACINTYREI (Bukry and Bramlette)

Plate 2, figs. 12–15

Coccolithus leptoporus (Murray and Blackman). McINTYRE, BÉ, and PREIKSTAS, 1967, Progress in Oceanography, vol. 4, p. 9 (partim), pl. 2, figs. A, B [not pl. 4, figs. C, D; pl. 5, figs. A, C, D = *Cyclococcolithina leptopora*].

Cyclococcolithus macintyrei BUKRY and BRAMLETTE, 1969, Tulane Stud. Geol. Paleont., vol. 7, no. 3, p. 132, pl. 1, figs. 1–3.

Cyclococcolithina macintyrei GARTNER, 1973, Geol. Soc. America, Bull., vol. 84, no. 6, p. 2021.

Discussion: This species is distinguished from *Cyclococcolithina leptopora* by its larger size, 11 microns compared with 6 microns, and by the consistently larger number of elements in either shield.

Bukry (1971a) noted that in some areas it is possible to subdivide the late Pliocene *Discoaster brouweri* zone into several subzones; the latest of these is the *Cyclococcolithina macintyrei* subzone. Distribution of this species in late Pliocene and early Pleistocene sediments on the Louisiana Continental Shelf coincides approximately with this subzone. Common occurrences (50 to 500 per traverse) are found in late Pliocene beds, and scarce (5 to 50 specimens per traverse) are reported from early Pleistocene strata.

Reported occurrences: Miocene to Pleistocene.

Genus UMBILICOSPHAERA Lohmann, 1902

Type species: *Umbilicosphaera mirabilis* Lohmann, 1902.

Definition: Circular placoliths possessing a short tube connecting the shields, the proximal shield is equal to, or smaller than the distal shield. The central perforation is large in most species.

UMBILICOSPHAERA MIRABILIS Lohmann
Plate 3, figs. 10–13

Umbilicosphaera mirabilis LOHMANN, 1902, Archiv. Protistenk., vol. 1, p. 139, pl. 5, figs. 66, 66a.

Umbilicosphaera mirabilis Lohmann. BLACK and BARNES, 1961, Roy. Micros. Soc., Jour., ser. 3, vol. 80, p. 140, pl. 25, figs. 4, 5.

Cyclococcolithus mirabilis (Lohmann). KAMPTNER, 1954, Archiv. Protistenk., vol. 100, p. 24, text-figs. 21–23.

Umbilicosphaera mirabilis Lohmann. McINTYRE, BÉ, and PREIKSTAS, 1967, Progress in Oceanography, vol. 4, p. 13, pl. 2, figs. C, D.

Umbilicosphaera mirabilis Lohmann. McINTYRE and BÉ, 1967, Deep-Sea Research, vol. 14, p. 571, 572, pl. 11, figs. B, C; pl. 11, fig. A.

Discussion: McIntyre and Bé (1967) noted that in modern specimens the ultrastructure of this species varies with environmental conditions. In colder waters the placoliths are heavier, the distal shield is larger, and the central perforation is smaller than in warm water specimens.

In the Terrebonne Shale the warm water form is common. Specimens when viewed in cross-polarized light produce a distinct black interference cross.

Reported occurrences: Pliocene to Holocene.

Genus EMILIANIA Hay and Mohler, 1967

Type Species: *Pontosphaera huxleyi* Lohmann, 1902.

Definition: Placoliths with the distal shield constructed of I-shaped segments and the proximal shield constructed of I-shaped or petaloid elements.

TABLE 3

VARIETIES OF *CYCLOCOCCOLITHINA LEPTOPORA* (Murray and Blackman)
(After McIntyre, Bé, and Preikstas, 1967).

Variety	Diameter of Distal Shield	Diameter of Proximal Shield	Number of Elements
"A"	7.4–11.8 microns	6.8–8.7 microns	40 ± 2
"B"	4.4–8.5 microns	4.0–6.5 microns	31 ± 2
"C"	4.1–7.5 microns	3.1–5.6 microns	19 ± 2

EMILIANIA ANNULA
(Cohen)
Plate 4, figs. 6–8

Coccolithites annulus COHEN, 1964, Micropaleontology, vol. 10, no. 2, p. 243, pl. 3, figs. 1a–e.

Cyclolithella annulus (Cohen). McINTYRE and BÉ, 1967, Deep-Sea Research, vol. 14, p. 568, pl. 5, figs. A–C.

Emiliania annula (Cohen). BUKRY, 1971, *in* WINTERER *et al.,* 1971, Initial Rpts., Deep Sea Drilling Project, vol. VII, p. 1514.

Discussion: Cohen (1964) described and figured four light micrographs and one drawing of a new species, *Coccolithites annulus.* His first three figures (Plate 3, figs. 1a, 1b, 1c) are plan views taken with phase contrast. It is obvious that the three figures represent different specimens but they appear to be conspecific. The fourth micrograph (fig. 1d), taken in cross-polarized light, may represent a fourth specimen. Unfortunately, no holotype was designated.

After Loeblich and Tappan (1963) showed that the generic name *Coccolithites* is invalid, McIntyre and Bé (1967) placed this species in the genus *Cyclolithella* because of its cricolith

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	2. Electron photomicrograph, proximal view, var. "C", X 6750	
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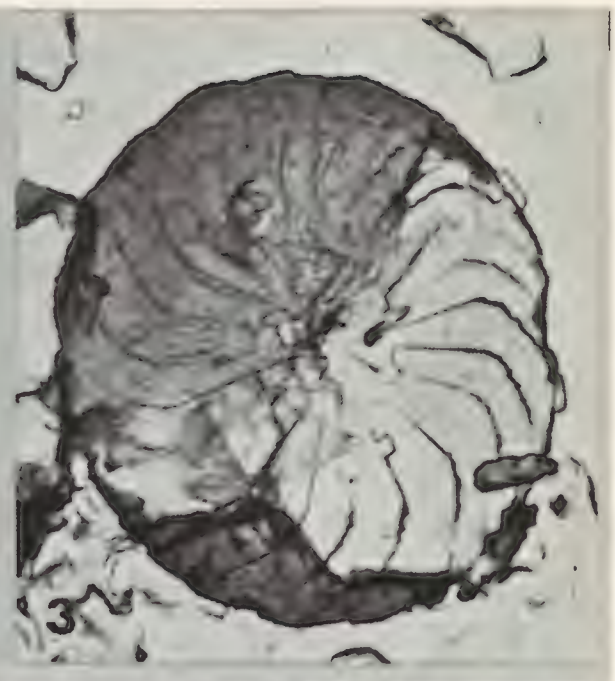
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PLATE 3

structure, but illustrated their paper only with transmission electron photomicrographs. Boudreaux (1968) presented both electron and light photomicrographs of this species. One of the electron photomicrographs, however, shows a subcircular placolith, which does not agree with the definition of this species by McIntyre and Bé (1967).

The specimen figured here (Plate 4, figs. 6–8) is similar to the phase contrast pictures of Cohen (1964) and Boudreaux (1968) but Boudreaux's cross-polarized light figure does not resemble Cohen's illustration. After examining numerous specimens in both phase contrast and cross-polarized light, the conclusion is reached that Cohen's cross-polarized light figure probably is a different species.

Bukry (1971a) re-evaluated this species and transferred it to the genus *Emiliania*. His study included detailed stratigraphic work which revealed abundance of *Emiliania annula* in earliest Pleistocene sediments, and he erected a subzone based on this species in the basal Pleistocene. His results are not supported by the present study as less than 50 specimens per traverse were encountered in the Louisiana Continental Shelf samples; therefore, his subzone cannot be recognized in this area.

Reported occurrences: Pleistocene and Holocene.

Family RHABDOSPHAERACEAE
Lemmermann, 1908
Genus RHABDOSPHAERA
Haeckel, 1894

Type species: *Rhabdosphaera clavigera* Murray and Blackman, 1898.

Definition: A rod or stem extending from the central portion of an elliptical disc on the distal side.

RHABDOSPHAERA CLAVIGERA
Murray and Blackman
Plate 5, figs. 5–9

Rhabdosphaera clavigera MURRAY and BLACKMAN, 1898, Roy. Soc. London, Phil. Trans., ser. B, vol. 190, p. 438, pl. 15, figs. 13–15.

Rhabdosphaera stylifera LOHMANN, 1902, Archiv. Protistenk., vol. 1, p. 143, pl. 5, fig. 65.

Discolithus phaseolus BLACK and BARNES, 1961, Roy. Micros. Soc., Jour, ser. 3, vol. 80, p. 144, pl. 26, figs. 1–4.

Ahmuellerella phaseolus (Black and Barnes). REINHARDT, 1964, Deutsch. Akad. Wiss., Monatsber., vol. 6. p. 751.

Rhabdosphaera stylifera Lohmann. McINTYRE and BÉ, 1967, Deep-Sea Research, vol. 14, p. 567, pl. 4, figs. A–C.

Rhabdosphaera clavigera Murray and Blackman. COHEN and REINHARDT, 1968, Neues Jahrb. Geologie Paläontologie, Abh., vol. 131, no. 3, p. 292, pl. 19, figs. 18, 22; pl. 20, figs. 6, 7; pl. 21, fig. 4.

Aspidorhabdus stylifer (Lohmann). BOUDREAUX and HAY, 1969, Rev. Española Micropaleontologia, vol. I, num. 3, p. 269, pl. IV, figs. 11–15.

Discussion: In view of the research by McIntyre and Bé (1967) on modern Coccolithophoridae, *Rhabdosphaera stylifera* and *Discolithus phaseolus* are placed in synonomy with *Rhabdosphaera clavigera*. They demonstrated that *Rhabdosphaera clavigera* and *Rhabdosphaera stylifera* intergrade in both plankton and sediment samples. Furthermore, they state that no zoogeographic differences can be demonstrated between them. Unfortunately, these authors mistakenly placed *Rhabdosphaera clavigera* in synonomy with *Rhabdosphaera stylifera* although the former has priority over *Rhabdosphaera stylifera* by four years.

Discolithus phaseolus is the separated basal plate of *Rhabdosphaera clavigera*. It is common in late Pliocene and early Pleistocene sediments.

Reported occurrences: Miocene to Holocene

Family THORACOSPHAERACEAE
Deflandre, 1952

Genus THORACOSPHAERA
Kamptner, 1927

Type species: *Thoracosphæra pelagica* Kamptner, 1927.

Definition: Coccolithophores with a spherical to subspherical test constructed of regularly or irregularly shaped polygonal elements of calcite.

THORACOSPHAERA SAXEA
Stradner
Plate 5, figs. 10–12

Thoracosphaera sp. BRAMLETTE and RIEDEL, 1954, Jour. Paleontology, vol. 28, no. 4, p. 393, pl. 38, fig. 5.
Thoracosphaera saxea STRADNER, 1961, Erdöl–Zeitschr., vol. 77, p. 84, text-fig. 71.
Thoracosphaera saxea Stradner. COHEN, 1964, Micropaleontology, vol. 10, no. 2, p. 248, pl. 5, figs. 6a–e; pl. 6, fig. 6.

Description: Small, irregular, imperforate polygonal elements, forming a spherical test. Contacts between plates appear crenulated.

Reported occurrences: Cretaceous to Holocene.

THORACOSPHAERA sp.
Plate 5, figs. 13–15

Description: Polygonal elements which are neither perforate or crenulated. Numerous species have been described by Kamptner (1967), but specific identification is difficult.

Family BRAARUDOSPHAERACEAE
Deflandre, 1947

Genus BRAARUDOSPHAERA
Deflandre, 1947

Type species: *Pontosphaera bigelowi* Gran and Braarud, 1935.

Definition: Pentagonal plates constructed of five calcite crystal units.

BRAARUDOSPHAERA BIGELOWI
(Gran and Braarud)
Plate 6, figs. 1–3

Pontosphaera bigelowi GRAN and BRAARUD, 1935, Jour. Biol. Board Canada, vol. 1, p. 389, text-fig. 67.
Braarudosphaera bigelowi (Gran and Braarud). DEFLANDRE, 1947, Comptes Rendus Acad. Sci., Paris, vol. 225, p. 439, text-figs. 1–5.
Braarudosphaera bigelowi (Gran and Braarud). BRAMLETTE and RIEDEL, 1954, Jour. Paleontology, vol. 28, no. 4, p. 393, pl. 38, figs. 6a, b.
Braarudosphaera bigelowi (Gran and Braarud). BRAMLETTE and SULLIVAN, 1961, Micropaleontology, vol. 7, no. 2, p. 153, pl. 8, figs. 1a, b, 2–5.
Braarudosphaera bigelowi (Gran and Braarud). HAY and TOWE, 1962, Science, vol. 137, no. 3528, p. 426, fig. 1.
Braarudosphaera bigelowi (Gran and Braarud). COHEN, 1965, Leidsche Geologische Mededelingen, vol. 35, p. 31, pl. 6, figs. a–d.

Discussion: Pentaliths composed of five elements. This long ranging species is of no stratigraphic value.

Reported occurrences: Cretaceous to Holocene.

Family PONTOSPHAERACEAE
Lemmermann, 1908

Genus HELICOPONTOSPHAERA
Hay and Mohler, 1967

Type species: *Helicopontosphaera kamptneri* Hay and Mohler, 1967.

Definition: Shallow lopadolith with a spirally expanding wall.

HELICOPONTOSPHAERA sp. cf.
HELICOPONTOSPHAERA INTERMEDIA
Martini
Plate 3, figs. 18–20

Helicosphaera intermedia MARTINI, 1965, Submarine Geology and Geophysics, Proc. 17th Symp. Colston Res. Soc., London, p. 404, pl. 35, figs. 1, 2.
Helicosphaera intermedia Martini. BRAMLETTE and WILCOXON, 1967, Tulane Stud. Geol., vol. 5, no. 3, p. 105, pl. 6, figs. 11, 12.
Helicopontosphaera intermedia (Martini). HAY, 1970, *in* BADER *et al.*, 1970, Initial Rpts., Deep Sea Drilling Project, vol. IV, p. 458.

Discussion: This species is distinguished from *Helicopontosphaera kamptneri* by a bar extending diagonally across the center, and the wing-like extension of the last spiral (see *Helicopontosphaera kamptneri.*)

Reported occurrences: Oligocene to Holocene.

HELICOPONTOSPHAERA KAMPTNERI
Hay and Mohler
Plate 3, figs. 21–24

Coccolithus carteri (Wallich). KAMPTNER, 1941, Naturh. Mus. Wien, Ann., vol. 51, p. 93, 111, pl. 13, fig. 136 [not *Coccosphaera carteri* Wallich, 1877, Ann. Mag. Nat. Hist., ser. 4, vol. 19, p. 348, pl. 17, figs. 3, 4, 6, 7, 17].
Helicosphaera carteri (Wallich). KAMPTNER, 1954, Archiv. Protistenk., vol. 100, no. 1, p. 21, text-figs. 17–19.
Helicosphaera carteri (Wallich). BLACK and BARNES, 1961, Roy. Micros. Soc., Jour., ser. 3, vol. 80, p. 139, pls. 22, 23.

Helicosphaera carteri (Wallich). COHEN, 1964, Micropaleontology, vol. 10, no. 2, p. 238, pl. 3, figs. 2a–f; pl. 4, figs. 1a–c.
Helicosphaera carteri (Wallich). COHEN, 1965, Leidsche Geologische Mededelingen, vol. 35, p. 21, pl. 3, figs. o–q; pl. 17, figs. a–d.
Helicosphaera carteri (Wallich) Kamptner. PYLE, 1966, Texas A & M Univ., Dept. Oceanography, Tech. Rept. 66–13T, p. 20, pl. 2, figs. 1, 2.
Helicosphaera carteri (Wallich) Kamptner. McINTYRE, BÉ, and PREIKSTAS, 1967, Progress in Oceanography, vol. 4, p. 12, pl. 6, figs. A, B.
Helicosphaera carteri (Wallich) Kamptner. McINTYRE and BÉ, 1967, Deep-Sea Research, vol. 14, p. 571, pl. 11, fig. A.

PLATE 4

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1–3 *Scyphosphaera apsteini* Lohmann 150
1. Phase contrast, X 2250
2. Crossed nicols, X 2250
3. Interference contrast, X 2250

4, 5 *Scyphosphaera pulcherrima* Deflandre 150
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20. Phase contrast, X 2250
21. Crossed nicols, X 2250

22–24 *Discolithina japonica* Takayama 151
22. Electron photomicrograph, X 5000
23. Phase contrast, X 2250
24. Crossed nicols, X 2250

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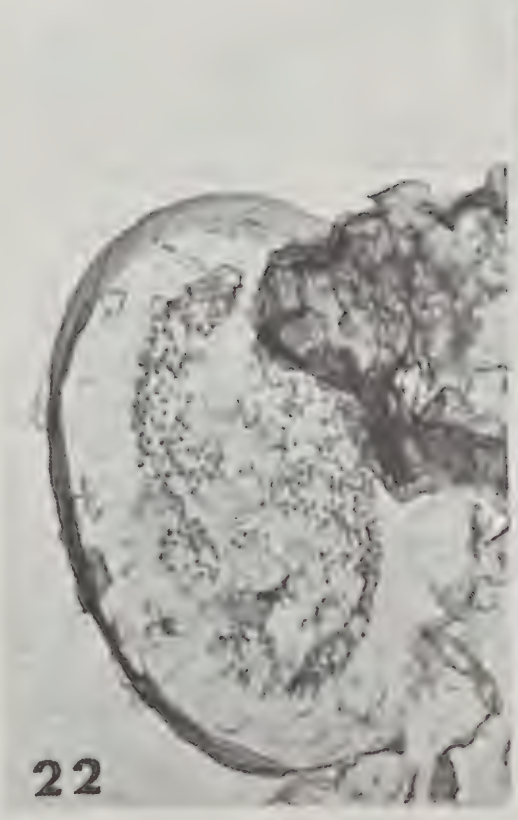
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PLATE 4

Helicopontosphaera kamptneri HAY and MOHLER, 1967, Gulf Coast Assoc. Geol. Soc., Trans., vol. XVII, p. 448, pls. 10, 11, fig. 5.

Helicopontosphaera kamptneri Hay and Mohler. HAY, 1970, *in* BADER *et al.*, 1970, Initial Rpts., Deep Sea Drilling Project, vol. IV, p. 458.

Discussion: This spirally coiled coccolith was described in detail by Black and Barnes (1961), but their electron micrographs are mirror images resulting in reversal of imbrication and suture directions.

The species may be confused with *Helicopontosphaera intermedia* (see above) which Martini (1965) separated on the basis of the bar that extends diagonally rather than directly across the center. Numerous workers have questioned this separation as there are morphological graduations between the two forms.

Reported occurrences: Miocene to Holocene.

Genus SCYPHOSPHAERA Lohmann, 1902

Type species: *Scyphosphaera apsteini* Lohmann, 1902.

Definition: Dimorphic coccolithophores bearing basket-like coccoliths called lopadoliths which are arranged in a circle along the equator of the outer cell wall.

SCYPHOSPHAERA APSTEINI Lohmann
Plate 4, figs. 1–3

Scyphosphaera apsteini LOHMANN, 1902, Archiv. Protistenk., vol. 1, p. 132, pl. 4, figs. 26–30.

Scyphosphaera apsteini Lohmann, 1902. DEFLANDRE, 1942, Bull. Soc. Hist. Nat. Toulouse, vol. 77, p. 130, figs. 10–15.

Scyphosphaera apsteini Lohmann. KAMPTNER, 1955, Kon. Nederl. Akad. Wetensch. Afd. Natuurkunde, Verh., ser. 2, vol. 50, no. 2, p. 22, text-figs. 109–112.

Scyphosphaera apsteini Lohmann. KAMPTNER, 1967, Naturh. Mus. Wien, Ann., vol. 71, p. 148, pl. 9, figs. 64–67; pl. 10, figs. 69–71.

Discussion: The lopadolith bears parallel ribs and furrows arranged vertically along the outer surface. The figured specimen closely resembles those of Kamptner (1955, 1967) and Boudreaux (1968).

The species is rare in the section studied.

Reported occurrences: Pliocene to Holocene.

SCYPHOSPHAERA PULCHERRIMA Deflandre
Plate 4, figs. 4, 5

Scyphosphaera pulcherrima DEFLANDRE, 1942, Bull. Soc. Hist. Nat. Toulouse, vol. 77, p. 133, figs. 28–31.

Syphosphaera pulcherrima Deflandre. BRAMLETTE and WILCOXON, 1967, Tulane Stud. Geol., vol. 5, no. 3, p. 107, pl. 10, fig. 5.

Discussion: This lopadolith is more robust in shape in the early Pleistocene sediments than the Miocene holotype. The more robust form is characteristic of late Neogene examples of this species. The main body is as wide or wider than the distal rim, the latter being slightly concave; the specimen depicted by Bramlette and Wilcoxon (1967) from the upper Cipero Formation lacks these two features.

Although this species is rare in the late Pliocene and early Pleistocene beds, this lopadolith is more common than *Scyphosphaera apsteini.*

Reported occurrences: Miocene to Pleistocene.

Genus DISCOLITHINA Loeblich and Tappan, 1963

Type species: *Discolithus vigintiforatus* Kamptner, 1948.

Definition: A single elliptical disc, generally perforated, with or without a rim.

DISCOLITHINA ANISOTREMA (Kamptner)
Plate 4, figs. 16–18

Coccolithites anisotrema KAMPTNER, 1955, Kon. Nederl. Akad. Wetensch. Afd. Natuurkunde, Verh., ser. 2, vol. 50, p. 16, 91, figs. 22a, b.

Discolithus anisotrema KAMPTNER, 1956, Anz. Österr. Akad. Wiss., Math.-Naturw. Kl., vol. 93, p. 9 [validated by reference to description and figure previously published under invalid name].

Discolithina cf. *D. anisotrema* (Kamptner). BRAMLETTE and WILCOXON, 1967, Tulane Stud. Geol., vol. 5, no. 3, p. 104, pl. 5, figs. 5, 6.

Discolithina anisotrema (Kamptner). HAY, 1970, *in* BADER *et al.*, 1970, Initial Rpts., Deep Sea Drilling Project, vol. IV, p. 458.

Discussion: The figured specimens are similar to those of Kamptner (1956). Immediately inside the rim, within the central area, is a circle of perforations that is developed in all forms. In most specimens additional perforations are present and arranged roughly in cycles; the total number of perforations varies between 75 and 100.

According to Bramlette and Wilcoxon (1967), "this taxon is one of a large number of inadequately described species which have been assigned to various genera." Unfortunately, many workers do not record such forms because of the questionable identifications and, thus, their stratigraphic distribution is uncertain.

Reported occurrences: Miocene to Pleistocene.

DISCOLITHINA JAPONICA
Takayama
Plate 4, figs. 22–24

Discolithina japonica TAKAYAMA, 1967, Jahrb. Geol. Wein, vol. 110, p. 177, 181.

Discolithina millepuncta GARTNER, 1967b, Univ. Kansas Paleont. Contr., paper 29, p. 5, pl. 8, fig. 4.

Description: A thin elliptical disc with numerous central perforations too small to be seen with the light microscope. The imperforate rim is broad, about one-fourth of the shorter diameter of the plate.

The central area is traversed by a longitudinal fissure visible in both electron and light micrographs, although this feature is obscured by clay in the electron micrograph figured here (fig. 22). The perforations in the central area are aligned diagonally, accounting for the radial appearance in the light photographs.

Reported occurrences: Pliocene and Pleistocene.

Family CALCIOSOLENIACEAE
Kamptner, 1937

Genus SCAPHOLITHUS
Deflandre, 1954

Type species: *Scapholithus fossilis* Deflandre, 1954.

Definition: An elongated rhomboidal rim with flat parallel lamellae extending from the sides of the rim to the middle of the central area.

SCAPHOLITHUS FOSSILIS
Deflandre
Plate 5, figs. 16–18

Scapholithus fossilis DEFLANDRE, 1954, *in* DEFLANDRE and FERT, Ann. Paléontologie, vol. 40, p. 165, pl. 8, figs. 12, 16, 17.

Scapholithus fossilis Deflandre. COHEN, 1964, Micropaleontology, vol. 10, no. 2, p. 244, pl. 3, figs. 4a–f; pl. 4, figs. 2a–c.

Scapholithus fossilis Deflandre. COHEN, 1965, Leidsche Geologisch Mededelingen, vol. 35, p. 24, pl. 3, figs. j–l; pl. 25, figs. a–d.

Discussion: Only the rhombic form is observable in the light microscope. In the electron micrograph, laths traversing the rhombic outline can be seen.

Reported occurrences: Cretaceous to Holocene.

Family SYRACOSPHAERACEAE
Lemmermann, 1908

Genus SYRACOSPHAERA
Lohmann, 1902

Type species: *Syracosphaera pulchra* Lohmann, 1902.

Definition: Dimorphic coccolithophores bearing caneoliths, those from the circumflagellar cycle bearing a central spine, others lacking spines.

SYRACOSPHAERA PULCHRA
Lohmann
Plate 4, figs. 12–15

Syracosphaera pulchra LOHMANN, 1902, Archiv. Protistenk., vol. 1, p. 124, pl. 4, figs. 33, 36, 37.

Syracosphaera pulchra Lohmann. SCHILLER, 1930, *in* L. RABENHORST, Kryptogamen-Flora, Leipzig, vol. 10, no. 2, p. 207, figs. 11, 30, 90a, b.

Syracosphaera pulchra Lohmann, 1902. DEFLANDRE and FERT, 1954, Ann. Paléontologie, vol. 40, figs. 1, 2 (?), 3, 4.

Syracosphaera pulchra Lohmann. BLACK and BARNES, 1961, Roy. Micros. Soc. Jour., ser. 3, vol. 80, p. 139, pl. 19, figs. 1, 2.

Syracosphaera pulchra Lohmann 1902. COHEN, 1965, Leidsche Geologische Mededelingen, vol. 35, p. 20, pl. 12, fig. d; pl. 14, figs. a, b.

Syracosphaera pulchra Lohmann 1902. COHEN and REINHARDT, 1968, Neues Jahrb. Geologie Paläontologie, Abh., vol. 131, no. 3, p. 292, pl. 20, fig. 3.

Description: The central area consists of radially arranged, lath-like elements which converge toward the center. These elements are not completely fused, and radial slits separate the adjacent laths. The outer margin or rim is constructed of about 50 imbricate elements.

Reported occurrences: Pliocene to Holocene.

SYRACOSPHAERA HISTRICA
Kamptner
Plate 4, figs. 9–11

Syracosphaera histrica KAMPTNER, 1941, Naturh. Mus. Wien, Ann., vol. 51, p. 84, pl. 6, figs. 65–68.
Discolithus histricus (Kamptner). COHEN, 1964, Micropaleontology, vol. 10, no. 2, p. 236, pl. 1, figs. 2a–g; pl. 2, fig. 1.
Discolithus aff. *histricus* (Kamptner). COHEN, 1965, Leidsche Geologische Mededelingen, vol. 35, p. 13, pl. 24, fig. a.

Discussion: This form produces a diagnostic interference figure in cross-polarized light. The central spine, formed by the fusion of slender elements radiating toward the center, is not seen in light micrographs.

Reported occurrences: Pliocene and Pleistocene.

Family ACANTHOIACEAE
Hay (in press)

Genus ACANTHOICA
Lohmann, 1903

Type species: *Acanthoica coronata* Lohmann, 1903.

PLATE 5

Figures — Page

1–4 *Cristallolithus macroporus* (Deflandre), n. comb. 154
1. Electron photomicrograph, X 13,750
2. Electron photomicrograph, X 5000
3. Phase contrast, X 2250
4. Crossed nicols, X 2250

5–9 *Rhabdosphaera clavigera* Murray and Blackman 146
5. Electron photomicrograph, X 5000
6. Crossed nicols, X 2250
7. Electron photomicrograph, X 5000
8. Phase contrast, X 2250
9. Electron photomicrograph, X 5000

10–12 *Thoracosphaera saxea* Stradner 147
10. Phase contrast, X 2250
11. Interference contrast, X 2250
12. Crossed nicols, X 2250

13–15 *Thoracosphaera* sp. 147
13. Phase contrast, X 2250
14. Interference contrast, X 2250
15. Crossed nicols, X 2250

16–18 *Scapholithus fossilis* Deflandre 151
16. Phase contrast, X 2250
17. Electron photomicrograph, X 9175
18. Crossed nicols, X 2250

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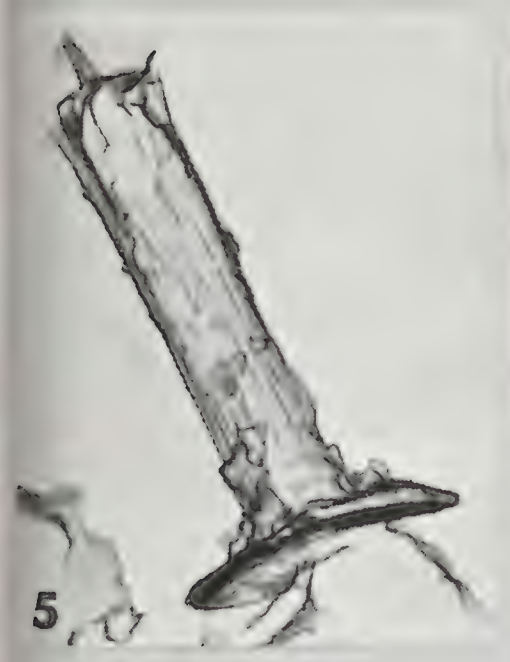
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PLATE 5

Definition: Coccosphere without an aperture, constructed of calyptroliths, inverted discoliths which are convex exteriorly with a central outgrowth.

ACANTHOICA sp.
Plate 4, figs. 19–21

Coccosphere in which the structure of the calyptroliths is not discernible.

Family ZYGOSPHAERACEAE
Hay (in press)

Genus HOMOZYGOSPHAERA
Deflandre, 1952

Type species: *Corisphaera spinosa* Kamptner, 1941.

Definition: Zygoliths which are not dimorphic.

HOMOZYGOSPHAERA WETTSTENI
(Kamptner)
Plate 6, figs. 9–12

Zygosphaera wettsteni KAMPTNER, 1937, Archiv. Protistenk., vol. 89, p. 306, pl. 16, figs. 30–32.
Cavosphaera wettsteni (Kamptner). LECAL and BERNHEIM, 1960, Bull. Soc. Hist. Nat. Afr. Nord, vol. 51, p. 293, pl. 21, fig. 25.
Homozygosphaera wettsteni (Kamptner). HALLDAL and MARKALI, 1955, Norske Vid.–Akad. Oslo, Mat.-naturv. Kl., Avh., no. 1, p. 9, pl. 5.

Discussion: Identification of this holococcolith is difficult when a side view showing the arches is not available. The electron micrograph (fig. 9) shows six pores, but in the light micrograph only four can be discerned. Possibly both are misidentified and actually belong to the species *Homozygosphaera quadriperforata* (Kamptner) Gaarder.

Reported occurrences: Pleistocene and Holocene.

Family CALYPTROSPHAERACEAE
Boudreaux and Hay, 1969

Genus CALYPTROSPHAERA
Lohmann, 1902

Type species: *Calyptrosphaera globosa* Lohmann, 1902.

Definition: Like *Acanthoica* but with an aperture.

CALYPTROSPHAERA OBLONGA
Lohmann
Plate 6, fig. 13

Calyptrosphaera oblonga LOHMANN, 1902, Archiv. Protistenk., vol. 1, p. 135, pl. 5, figs. 43–46.
Calyptrosphaera oblonga Lohmann. HALLDAL and MARKALI, 1955, Norske Vid.-Akad. Oslo, Mat.-naturv. Kl., Avh., vol. 1, p. 8, pl. 1.

Discussion: This holococcolith is constructed of numerous hexagonal prisms of uniform size, regularly arranged in a lattice with hexagonal openings. The rim consists of several layers of closely packed prisms without openings. Although the electron micrograph is of insufficient quality to perceive the individual prisms that constitute the coccolith, the hexagonal openings are visible.

The one specimen encountered is the first fossil representative of this species reported.

Reported occurrences: Pleistocene and Holocene.

Family CRISTALLOLITHACEAE
Hay (in press)

Genus CRISTALLOLITHUS
Gaarder and Markali, 1956

Type species: *Cristallolithus hyalinus* Gaarder and Markali, 1956.

Definition: Coccoliths constructed of rhombohedral prisms.

CRISTALLOLITHUS MACROPORUS
(Deflandre), new combination

Plate 5, figs. 1–4

Discolithus macroporus DEFLANDRE, 1954, *in* DEFLANDRE and FERT, Ann. Paléontologie, vol. 40, p. 24, pl. 11, fig. 5.
Discolithus macroporus Deflandre. STRADNER, 1962, Verh. Geol. Bundesanst. (Wien), p. 363, pl. 3.
Discolithus macroporus Deflandre. COHEN, 1964, Micropaleontology, vol. 10, no. 2, p. 236, pl. 3, figs. 5a–c; pl. 4, figs. 6a, b.
Discolithus macroporus Deflandre. COHEN, 1965,

Leidsche Geologische Mededelingen, vol. 35, p. 15, pl. 3, fig. u.

Discolithina macroporus (Deflandre). LEVIN and JOERGER, 1967, Micropaleontology, vol. 13, p. 167, pl. 2, fig. 5.

Discolithina macropora (Deflandre). REINHARDT, 1968, *in* COHEN and REINHARDT, Neues Jahrb. Geologie Palăontologie, Abh., vol. 131, no. 3, p. 298, pl. 19, fig. 24; pl. 20, fig. 9.

Discolithina ? macropora (Deflandre). GARTNER and BUKRY, 1969, Jour. Paleontology, vol. 43, no. 5, p. 1215, pl. 140, figs. 1, 2; pl. 142, figs. 3, 4.

Discussion: Gartner and Bukry (1969) recently recognized this species as a holococcolith, stating: "this species is constructed entirely of closely packed calcite rhombs" . . . and "the crystallites are not modified to conform to the configuration of the large pores or to the periphery."

The discovery of this microstructure requires that the species be transferred to the genus *Crystallolithus.*

Reported occurrences: Eocene to Holocene.

Family DISCOASTERACEAE
Tan Sin Hok, 1927

Genus DISCOASTER
Tan Sin Hok, 1927

Type species: *Discoaster pentaradiatus* Tan Sin Hok, 1927.

Definition: Stellate calcareous plates with radial rays. Asteroliths.

DISCOASTER BROUWERI
Tan Sin Hok
Plate 6, fig. 8

Discoaster brouweri TAN SIN HOK, 1927, Jaarb. Mijnw. Nederl.-Indie, vol. 55, p. 120, text-figs. 2, 8a, b.

Discoaster brouweri Tan Sin Hok, sens. emend., BRAMLETTE and RIEDEL, 1954, Jour. Paleontology, vol. 28, p. 402, pl. 39, fig. 12, text-figs. 3a, b.

Discoaster brouweri (Tan Sin Hok). MARTINI and BRAMLETTE, 1963, Jour. Paleontology, vol. 37, no. 4, p. 851, pl. 102, figs. 9, 10.

Discoaster brouweri Tan Sin Hok. BRAMLETTE and WILCOXON, 1967, Tulane Stud. Geol., vol. 5, no. 3, p. 109, pl. 8, fig. 12.

Discoaster brouweri Tan Sin Hok. HAY, 1970, *in* BADER *et al.,* 1970, Initial Rpts., Deep Sea Drilling Project, vol. IV, p. 460.

Discussion: The marked reduction in the numbers of individuals of this species between cores 20 and 21 (see figure 6) marks the top of the *Discoaster brouweri* zone as defined by Bukry (1971b). Scarce specimens (5 to 50 per traverse) are recorded from core 18, but this small increase occurs at the base of the transgressive phase and is attributed to reworking in the lower Terrebonne Shale.

Family CERATOLITHACEAE
Norris, 1965

Genus CERATOLITHUS
Kamptner, 1950

Type species: *Ceratolithus cristatus* Kamptner, 1950.

Definition: Coccolithophores bearing horseshoe-shaped bodies or ceratoliths.

CERATOLITHUS CRISTATUS
(Kamptner)
Plate 6, figs. 4-5

Ceratolithus cristatus KAMPTNER, 1954, Archiv. Protistenk., vol. 100, p. 43, text-figs. 44–55.

Ceratolithus cf. *C. cristatus* (Kamptner). BRAMLETTE and RIEDEL, 1954, Jour. Paleontology, vol. 28, no. 4, p. 394, pl. 38, fig. 9.

Ceratolithus cristatus (Kamptner). COHEN, 1964, Micropaleontology, vol. 10, no. 2, p. 244, pl. 5, figs. 5a–d; pl. 6, fig. 5.

Ceratolithus cristatus (Kamptner). COHEN, 1965, Leidsche Geologische Mededelingen, vol. 35, p. 36, pl. 3, figs. m, n.

Ceratolithus cristatus (Kamptner). NORRIS, 1965, Archiv. Protistenk., vol. 108, p. 19–24, pls. 11–13.

Ceratolithus cristatus Kamptner, emended. BUKRY and BRAMLETTE, 1968, Tulane Stud. Geol., vol. 6, no. 4, p. 150, pl. 1, figs. 1–4.

Ceratolithus cristatus Kamptner. HAY, 1970, *in* BADER *et al.,* 1970, Initial Rpts., Deep Sea Drilling Project, vol. IV, p. 459.

Discussion: The revisions of *Ceratolithus* by Gartner (1967b) and Bukry and Bramlette (1968) are major contributions to the stratigraphic zonation of the Neogene. As originally defined, this species included all ceratoliths. Gartner named *Ceratolithus tricorniculatus,* a pre-Pleistocene form; Bukry and Bramlette (1968) emended both species and erected a third, *Ceratolithus rugosus,* for late Miocene to early Pleistocene forms. All three are readily distinguishable and morphological gradations between *Ceratolithus cristatus* and *Ceratolithus*

rugosus occur only near the Pliocene-Pleistocene contact (Bukry and Bramlette, 1968).

Ceratolithus rugosus possesses the same crystallographic orientation as *Ceratolithus cristatus* but differs in its rugose surface and robust development. In *Ceratolithus cristatus* the arms are generally smooth but may be notched. Under cross-polarized light the form is dark when the axis of the horseshoe is parallel to the vibration direction of either nicol and uniformly bright when rotated 45 degrees.

Reported occurrences: latest Pliocene to Holocene.

"Family" INCERTAE SEDIS
Genus CRICOLITHUS
Kamptner, 1958

Type species: *Cricolithus multiradiatus* Kamptner, 1958.

Definition: Isolated ring of elliptical outline.

CRICOLITHUS JONESI Cohen

Plate 3, figs. 14–17

Cricolithus jonesi COHEN, 1965, Leidsche Geologische Mededelingen, vol. 35, p. 16, pl. 2, figs. j, k; pl. 16, figs. a–c.

Discussion: This simple elliptical ring of about 30 elements is distinctive in both the electron and light microscopes. The light micrograph is identical to the holotype but the electron micrograph (fig. 14) differs from Cohen's in that two rings appear to be present instead of one; however, this may be due to the poor quality of the micrograph.

Reported occurrences: Pleistocene and Holocene.

PLATE 6

Figures		Page
1–3	*Braarudosphaera bigelowi* (Gran and Braarud)	147
	1. Phase contrast, X 2250	
	2. Electron photomicrograph, X 3650	
	3. Crossed nicols, X 2250	
4, 5	*Ceratolithus cristatus* (Kamptner)	155
	4. Phase contrast, X 2250	
	5. Crossed nicols, X 2250	
6, 7	*Discoaster pentaradiatus* Tan Sin Hok [contamination]	155
	6. Phase contrast, X 2250	
	7. Crossed nicols, X 2250	
8	*Discoaster brouweri* Tan Sin Hok	155
	8. Phase contrast, X 2250	
9–12	*Homozygospira wettsteni* (Kamptner)	154
	9. Electron photomicrograph, X 9175	
	10. Phase contrast, X 2250	
	11. Interference contrast, X 2250	
	12. Crossed nicols, X 2250	
13	*Calyptrosphaera oblonga* Lohmann	154
	13. Electron photomicrograph, X 11,000	

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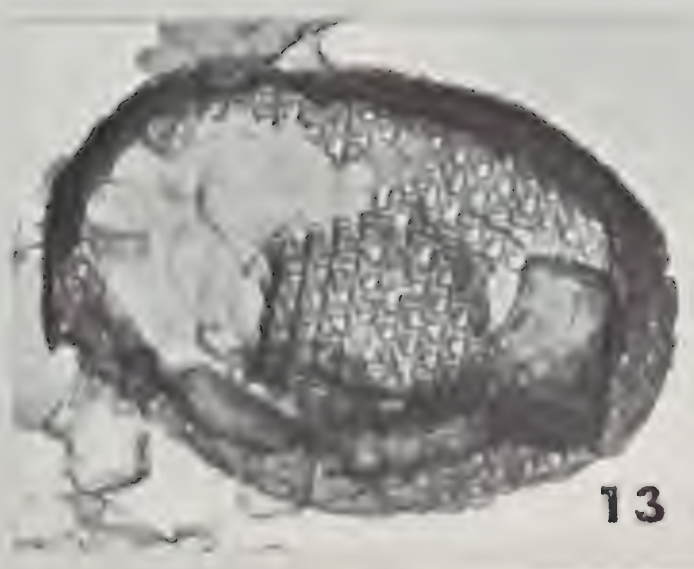
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PLATE 6

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EMILY H. VOKES

Tulane University

Listed below are all biologic names to be found in the first ten volumes of this journal. All species-group names are cited equally, even though in the text they may appear as subspecies. Included are all primary references, such as systematic discussions, illustrations, and diagrams. However in any paper a species may appear many times, therefore all primary references are listed but not the secondary references. If there is no primary reference for a species, in most cases the first appearance of the name then appears in the Index. Abstracts and charts are not indexed, as it is assumed that the species name appears elsewhere in the text. The Roman numeral indicates the volume number and all new taxa are printed in bold-face type, including the page where the original description is given.

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Volume 11, Number 1 January 9, 1974

CALCAREOUS NANNOFOSSIL SYSTEMATICS, PALEOECOLOGY, AND BIOSTRATIGRAPHY OF THE MIDDLE EOCENE WECHES FORMATION OF TEXAS

RONALD W. SHERWOOD
AMOCO PRODUCTION COMPANY
NEW ORLEANS, LOUISIANA p. 1

CALCAREOUS NANNOFOSSILS OF THE LOUISIANA CONTINENTAL SHELF: ADDITIONS AND CORRECTIONS

HUBERT C. SKINNER
TULANE UNIVERSITY p. 80

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Tulane Studies in Geology and Paleontology
Department of Geology
Tulane University
New Orleans, Louisiana 70118
U.S.A.

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AMOCO PRODUCTION COMPANY
NEW ORLEANS, LOUISIANA

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I. ABSTRACT

Eighty previously described species of calcareous nannofossils representing 25 genera are figured with scanning-electron micrographs and photomicrographs. Improved criteria for identifying and distinguishing species and genera are presented based upon their appearance in the scanning-electron microscope. Nine new combinations are formed.

Based upon the stratigraphic range of key species, the *Discoaster lodoensis* Zone, *Discoaster sublodoensis* Zone, *Discoaster tani* s.l.-*Sphenolithus radians* Zone, *Reticulofenestra umbilica-Sphenolithus furcatolithoides* Zone, *Pemma papillatum* Zone, *Reticulofenestra* Datum and *Discoaster saipanensis* Datum of Gartner's 1971 Paleogene Nannofossil Zonation are recognized. The positions of two missing zones, *Bramletteius serraculoides* Zone and *Chiphragmalithus quadratus* Zone, have been inferred.

Variations in the occurrence and abundance of species between outcrop and subsurface samples were found to exist. These variations may be the result of differential preservation or the result of living species being restricted to particular areas of the neritic environment. The following species were found only in the subsurface portion of the Weches and are considered indicators of the outer neritic environment:

Chiasmolithus titus
Pontosphaera plana
Pontosphaera versa
Micrantholithus procerus
Sphenolithus furcatolithoides
Sphenolithus obtusus
Trochoaster radiatus
Discoaster aster
Discoaster diastypus
Discoaster triangularis
Discoaster woodringi

The following species were found to occur in several subsurface samples but appeared in only one or two outcrop samples. These species probably could live throughout the neritic environment but preferred deeper portions or were better preserved in deeper water deposits.

Chiasmolithus grandis
Pontosphaera pectinata
Braarudosphaera discula
Micrantholithus flos
Micrantholithus ornatus
Helicopontosphaera lophota
Rhabdolithes rudis
Discoaster stella
Discoaster barbadiensis
Discoaster saipanensis
Discoaster tani nodifer

Lophodolithus rotundus and *Marthasterites furcatus* occurred exclusively in outcrop samples. *Chiasmolithus bidens, Blackites amplus* and *Trochoaster simplex* occurred several times in outcrop samples but each is found only once in the subsurface. These five species are considered indicative of the middle to inner neritic environment. *Cyclococcolithina formosa, Cruciplacolithus staurion,* and *Zygrhablithus bijugatus* occurred in both subsurface and surface samples but were generally present in greater abundance in subsurface samples. *Ericsonia muiri, Reticulofenestra coenura, Koczyia wechesensis, Traversopontis pulchriporus, Blackites tenuis,* and *Discoaster elegans* were present in greater abundance in outcrop samples.

II. INTRODUCTION

Calcareous nannofossils are small fossilized carbonate bodies (1-50 microns) produced by two distinct groups of organisms. These are the ascidians, which are marine protochordates, and the coccolithophores, unicellular golden-brown algae of the Division Chrysophyta. The fossil record of the ascidians is sparse, and shows little evolutionary change, but fossilized coccolithophores are abundant in marine sediments and show many evolutionary changes (Haq, 1971d).

The coccolithophores are a group of largely marine, planktonic algae. Diversely shaped calcareous bodies, known as coccoliths, are produced during some phase of their life cycle. Coccoliths may be constructed of uniform calcite crystals, in which case they are known as holococcoliths (Braarud, *et al.,* 1955). However, heterococcoliths (Braarud *et al.,* 1955),

constructed of variously shaped calcite elements, are more common. Holococcoliths have been observed to be formed outside the cytoplasmic membrane but inside an outer membrane of the algal cell (Manton and Leedale, 1963). Heterococcoliths, however, are produced on a preformed organic template within the protoplasm of the cell and subsequently migrate to the cell surface (Wilbur and Watabe, 1963). Here they are extruded and form an external covering. The resulting test, composed of interlocking coccoliths, is known as a coccosphere.

An organic membrane coats the surface of each coccolith and probably serves to retard dissolution (Cita, 1971). Upon the death of the algal cell the coccosphere disaggregates and settles to the ocean floor. Coccoliths and rare coccospheres have been found in marine sediments from the early Jurassic to the Holocene with single unconfirmed reports of coccoliths being found in the Permian (Pirini Radrizzani, 1971) and Pennsylvanian (Noël, 1965).

Star-shaped carbonate bodies known as discoasters first appeared in the Paleocene in association with coccolith species. Discoasters persisted throughout most of the Cenozoic, becoming extinct during the Pliocene and only rare and questionable occurrences are known from the Pleistocene. During this time they too underwent many evolutionary changes (Haq, 1971d; Prins, 1971). By reason of their common occurrence with coccolithophores, discoasters are assumed to have also been produced by pelagic algae. The term nannofossil(s) has come to be used in a general sense when referring to calcareous fossils believed related to the coccolithophores and will be so used in this paper.

The planktonic habit of the calcareous nannofossils made it possible for the many new species to spread quickly throughout the oceans of the world. This along with the large number of specimens recoverable from small samples makes them ideal for transoceanic correlations and for subdividing marine strata into biostratigraphic zones (Bramlette and Wilcoxon, 1967; Hay *et al.*, 1967; Gartner, 1969, 1971; Roth, 1970; Martini, 1971c; Edwards, 1971; Hornibrook and Edwards, 1971).

At present the ecology and paleoecology of calcareous nannofossils is poorly understood. Fossil assemblages have been found in sediments deposited under marine to slightly brackish conditions. Open-ocean and shelf assemblages have been identified, although the reasons for such provincialism in planktonic organisms are not yet known. It is currently believed that dissolution of certain species is an important factor in the production of fossil assemblages indicative of environments of deposition. The middle Eocene Weches Formation of Texas was selected for study in an effort to gain a better understanding of the paleoecology of the nannofossils of the neritic environment.

The Weches is a relatively thin transgressive marine formation deposited conformably upon the regressive Queen City Formation of Texas. The formation consists of fossiliferous glauconitic clays, marls and limestones deposited within the neritic environment. The Weches Formation was selected for examination because a great deal was known about its paleoecology; foraminifera, ostracoda and larger marine invertebrates having been studied in detail (Stenzel, 1945; Stephenson, 1946; Feray, 1948; Curtis, 1955; Shafiq, 1969; Guevara and Garcia, 1972). It was also known that a well-developed flora of nannofossils existed although they had not been studied systematically (Bramlette and Sullivan, 1961).

III. ACKNOWLEDGMENTS AND DEPOSITORY OF TYPES

I wish to thank Dorothy J. Echols and Harold L. Levin of the Department of Earth Sciences, Washington University, St. Louis, Missouri, for their assistance and encouragement during this research. Thanks are also due Marie Greider and Edward Finke of the Department of Pathology, Washington University Medical School, for their generous cooperation and assistance in making the scanning-electron microscope

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The writer is also grateful to William R. Walton, Geological Research Director, Amoco Production Company, Tulsa, Oklahoma, for making samples available and to Melvin L. Shourd for assistance in the field.

This work was supported by a Grant-in-Aid of Research from the Society of the Sigma Xi and the Washington University Graduate School Faculty Research Fund. The scanning-electron microscope was made available through Health Science Advancement Award F-304-FR 06115 to Washington University.

Light-microscope slides and SEM negatives prepared for this study have been deposited in the Washington University Micropaleontological Collection (W.U.M.C), Department of Earth Sciences, Washington University, St. Louis, Missouri, 63130.

Hypotype data for figured specimens is given in the following format with photomicrographs listed first, followed by SEM micrographs. The name of the outcrop from which the sample was collected appears, followed by the letter designation of the sample (Figure 2). County name, well number and depth in feet are reported for subsurface samples. Following the sample and location data for photomicrographs, slide coordinates in parentheses, the W.U.M.C. number and the size of the specimen are given. If the specimen in the SEM micrograph is from a different locality or sample the appropriate data is given, followed by the number of the SEM negative designated as hypotype and the specimen size. Several specimens from a sample collected along the Sabine River appear as figured specimens. The stratigraphic position of this sample within the Weches Formation is not known. This sample is referred to as Sabine River E in the hypotype data.

IV. STRATIGRAPHY AND PALEOECOLOGY

The Weches Formation in Texas has been assigned to the middle Eocene Claiborne Group in Texas. It is correlative with the Cane River Formation in Louisiana, the Winona Formation in Mississippi, the lower Lisbon Formation in Alabama and the upper Lake City Limestone in Florida. The name Weches was proposed by Wendlandt and Knebel (1929, p. 1356) to designate the clayey glauconitic beds below the Sparta Sands and above the Queen City Sands. However, no type locality was designated. Stenzel (1944) subsequently designated as type localities, outcrops of the Weches in three roadcut sections on Texas State Highway 21 west of Weches, Texas. Regrettably these type sections are leached and oxidized, making them unsuitable for paleontological study.

In 1938 Stenzel divided the Weches Formation into three members: the Tyus, Viesca, and Therrill, but in 1952 he elevated the Therrill Member to the rank of formation. The Tyus Member is a slightly glauconitic calcareous marl containing the oyster *Ostrea lisbonensis* Harris, many irregular lime nodules, a limestone bench or bedded limestone concretions and few fossils. According to Stenzel, limestone or lime nodules are the outstanding component of the Tyus Member. The Viesca Member is a poorly bedded, fossiliferous, argillaceous, calcareous glauconitic unit. Glauconite is the outstanding feature of this member.

The marine character of the Weches persists throughout eastern and south central Texas, changing to a gypsiferous, carbonaceous, sandy clay near the margin of the Rio Grande Embayment. The formation becomes generally nonmarine and indistinguishable from the Queen City where the two formations merge into the El Pico Clay (Eargle, 1968).

Feray (1948) examined the environmental significance of foraminifera as related to the sedimentary characteristics of the Weches Formation. He concluded that the Tyus facies represented:

> "Sediments deposited in warm, shallow, agitated marine water that was relatively clear. The presence of glauconite, an abundance of shell fragments, and an absence of bedding indicates slow sedimentation and thorough reworking of sediments by burrowing and mud-eating benthonic

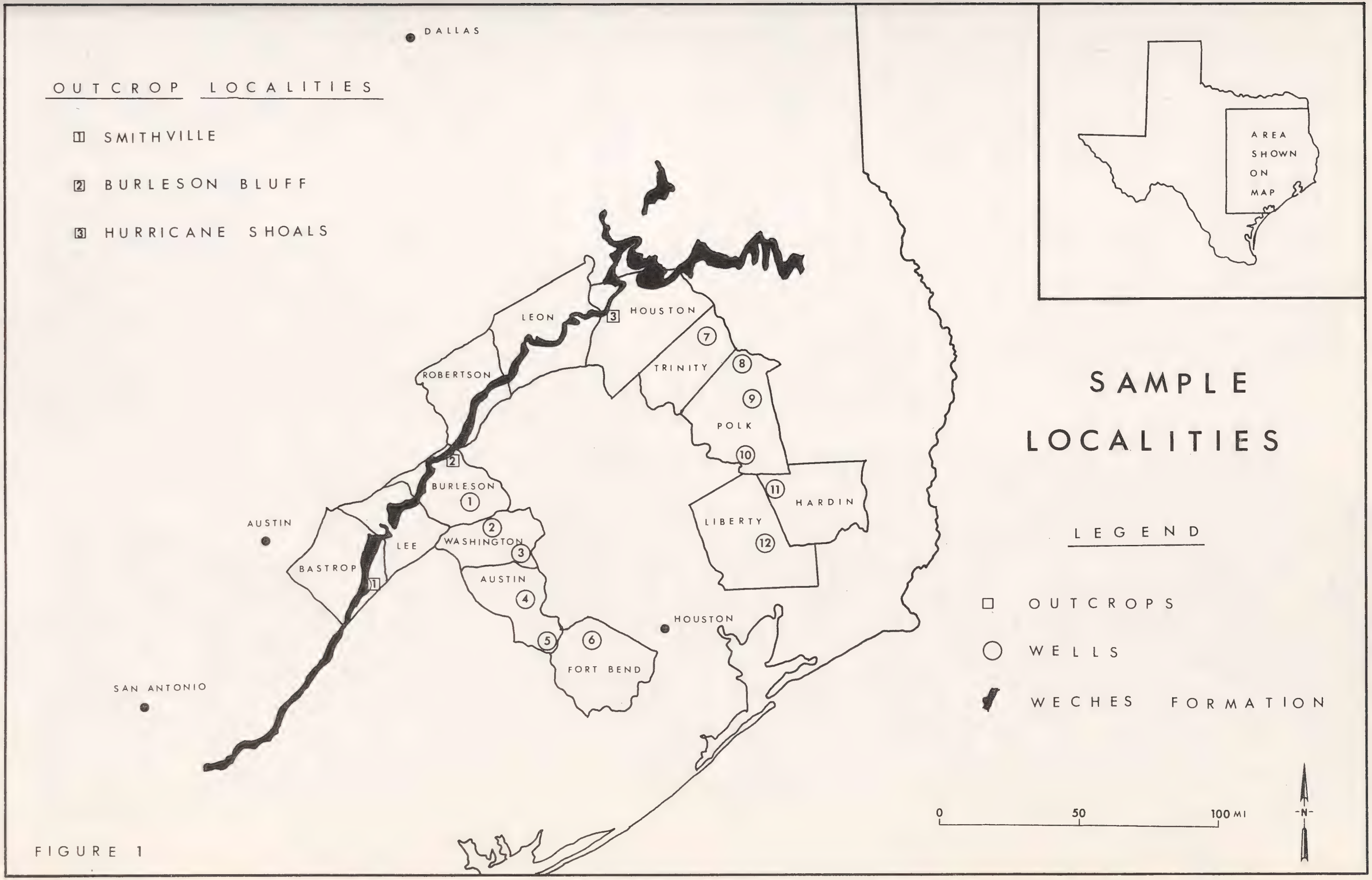

DALLAS
OUTCROP LOCALITIES
1 SMITHVILLE
2 BURLESON BLUFF
3 HURRICANE SHOALS
AREA SHOWN ON MAP
SAMPLE LOCALITIES
LEGEND
OUTCROPS
WELLS
WECHES FORMATION
LEON
HOUSTON
ROBERTSON
TRINITY
POLK
HARDIN
LIBERTY
BURLESON
WASHINGTON
LEE
BASTROP
AUSTIN
FORT BEND
AUSTIN
SAN ANTONIO
HOUSTON
0
50
100 MI
N

FIGURE 1

> organisms. The Tyus sediments were deposited in water which probably was not over five to six fathoms deep." (Feray, 1948, p. 189)

The Viesca facies, he believed, represented sediments deposited at a slow rate, within the neritic zone, in water slightly deeper than the Tyus facies. Feray cited the abundance of glauconitized fecal pellets as evidence of slow accumulation of clay in quiet water, with reworking by benthonic organisms allowing glauconitization of the fecal pellets. He estimated the depth of water in which the Viesca was deposited to be 6 to 15 fathoms. However, in a concluding paragraph Feray remarked that the uniform occurrence of the foraminifera genera *Quinqueloculina* and *Triloculina* throughout the Tyus and Viesca suggests a greater depth of water, possibly to 30 fathoms. Feray's paleoecological interpretations are in agreement with Stenzel's macrofossil data (1938; 1945) and were based on Lowman's (1949) investigations of the distribution of foraminifera in the Gulf of Mexico.

In 1955, Curtis reexamined a portion of the Viesca Member of the Weches Formation at Smithville, Texas. He recognized four depth zones based upon the inverse frequency relationship of *Quinqueloculina claiborniana* to *Siphonina claibornensis* and the presence of an oyster bed. The depth zones were considered to be within a range of 1–100 meters.

Shafiq (1969) reexamined the Burleson Bluff section that was studied by Feray. He reconstructed the paleoenvironment using the abundance and species diversity of the calcareous-perforate, calcareous-imperforate and arenaceous foraminifera as well as the foraminifera/ostracoda ratio. Based upon these data, he concluded that the:

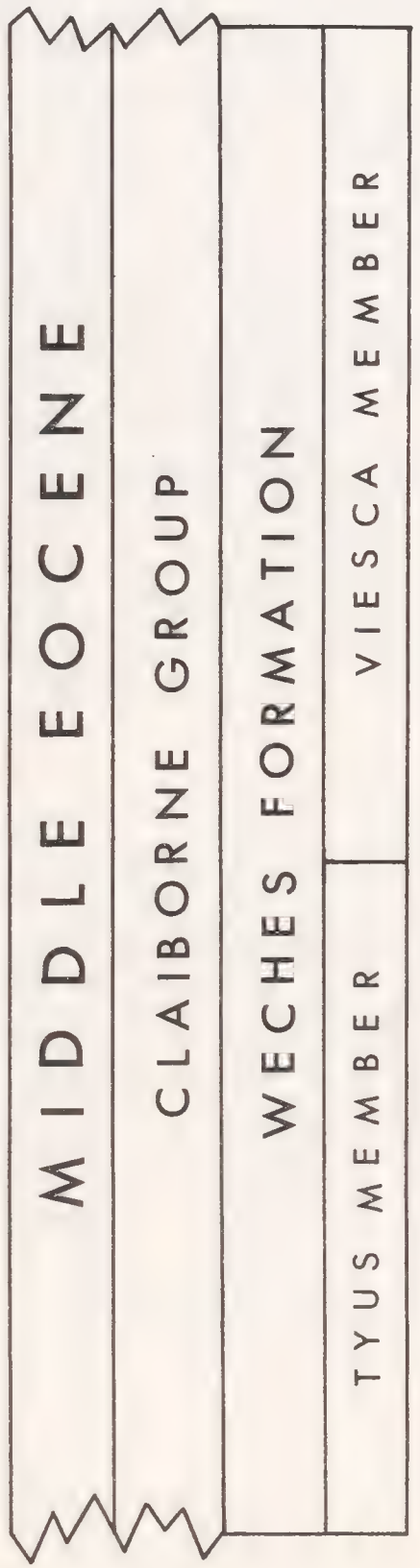
> "(7) Weches Formation at the localities studied was deposited in environments with water depth not deeper than middle shelf (app. 328 feet).
>
> (8) Presence of the foraminiferal genus *Asterigerina* and abundant filter feeders such as corals and bryozoans indicate the water was generally shallow, warm, clear, and of normal salinity.
>
> (9) Presence of clay and fine silt deposits and associated filter feeders indicate the currents were generally weak during the deposition of the Weches sediments. Well worn foraminiferal shells are the result of post-depositional chemical conditions and not physical abrasion of wave action.
>
> (10) A moderately slow rate of sedimentation in the Weches Formation is indicated by homogeneous and poorly sorted sediments which have been completely reworked by a diverse infauna of molluscs, ostracodes and crustaceans." (Shafiq, 1969, p. 78)

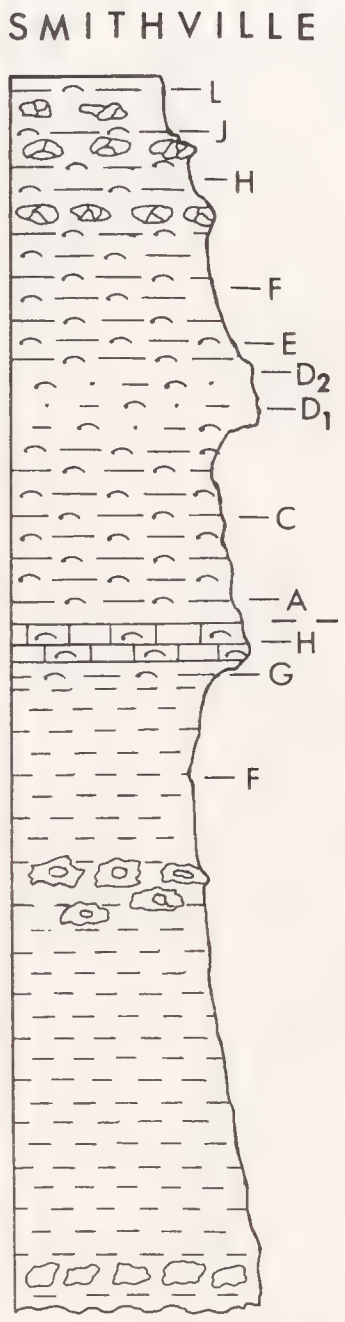
These previous studies based on foraminifera and macrofossil paleontology and sedimentary characteristics indicate that the Weches sediments now exposed were deposited in water depths ranging from one to 100 meters. Feray noted a maximum of 48 species of foraminifera for the Tyus Member in the outcrop section at Burleson Bluff, Burleson County, Texas; and a maximum number of 67 species for the Viesca Member was found at the Smithville outcrop, Bastrop County, Texas (Figure 1).

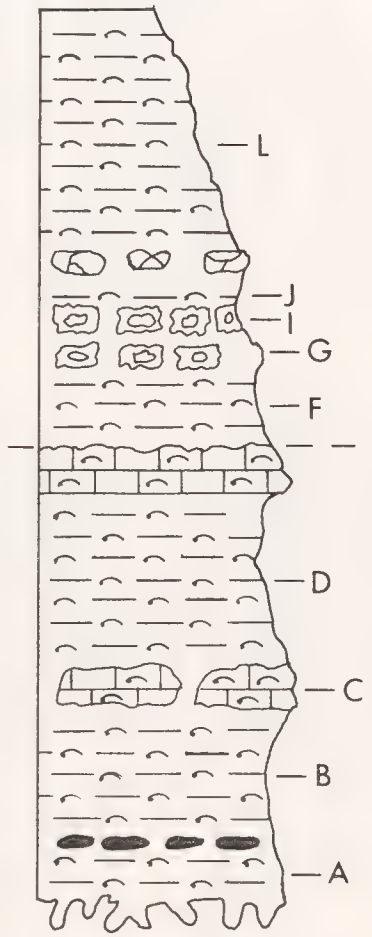
V. OUTCROP AND SUBSURFACE SAMPLE DESCRIPTIONS

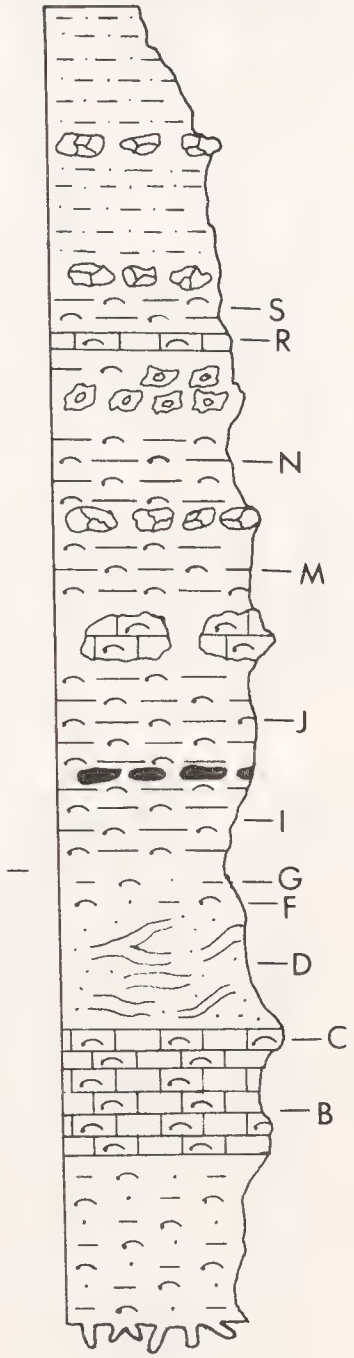
Outcrop samples utilized in this investigation represent portions of larger samples originally collected by H. B. Stenzel and Daniel Feray and used by Feray in his doctoral dissertation (1948). These outcrop samples are retained by Amoco Production Company as standards of reference for part of the Texas Tertiary. Smear slides of the entire group of samples were examined to determine those most suitable for this investigation. On the basis of their nannofossil content and the thickness of vertical exposure, three sections were selected for detailed study. These outcrop sections are located along the Colorado River at Smithville, Bastrop County; the Brazos River at Burleson Bluff, Burleson County; and the Trinity River at Hurricane Shoals, Houston County, Texas (Figures 1, 2). These localities bear the following Texas Bureau of Economic Geology locality

STRATIGRAPHIC SECTION









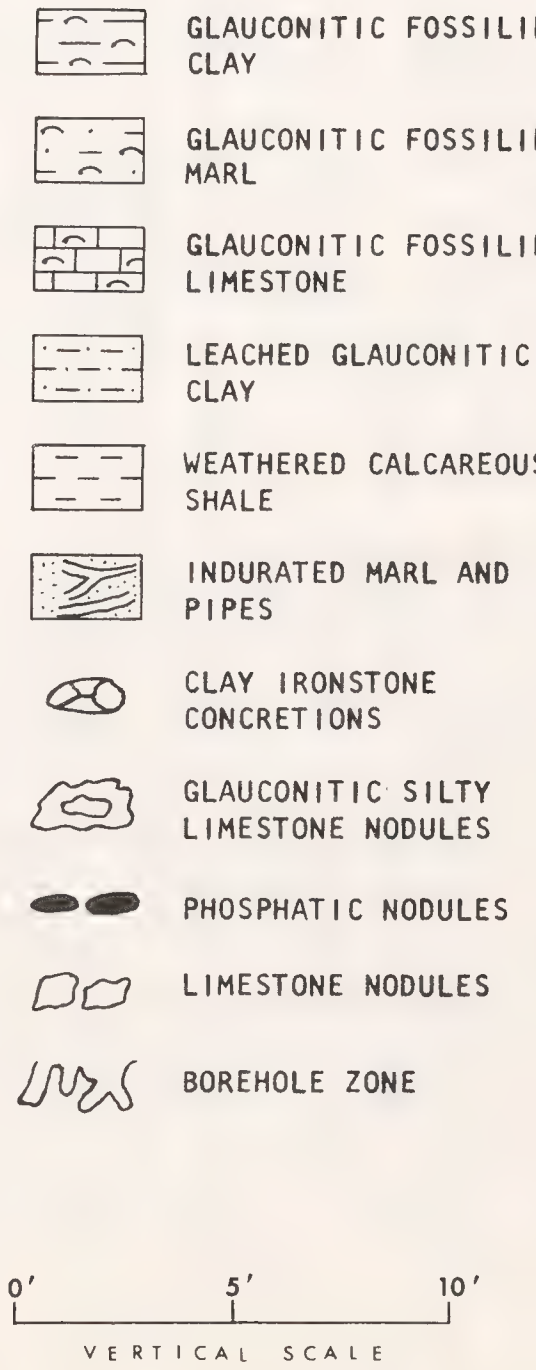


FIGURE 2

AFTER FERAY 1948

numbers: Smithville, 11-T-2; Burleson Bluff, 26-T-6; Hurricane Shoals, 113-T-15.

Samples of the subsurface Weches Formation were also obtained from Amoco Production Company. Cuttings were examined from twelve wells (Figure 1) located to the south of the belt of Weches exposures. Three samples representing portions of the lower, middle and upper Weches Formation were obtained from each well. The top of the subsurface Weches Formation was recognized by the occurrence of the foraminifera *Textularia smithvillensis* Cushman and Ellisor in Cushman, 1933, or *Lamarckina claibornensis* Cushman, 1929, and a down-dip equivalent, *Bifarina turriformis* Hussey, 1943.

VI. SAMPLE PREPARATION

A five gram portion of each sample was placed in 50 ml of distilled water. After standing for an hour, the samples were disaggregated in an ultrasonic cleaner for one minute, followed by agitation for 24 hours. Outcrop material was loosely disaggregated in less than five minutes. Well cuttings, however, were mainly well-indurated shale chips requiring much more time for disaggregation.

Portions of the final suspension to be examined in the light microscope were obtained by shaking the sample jar vigorously, letting it stand for ten to 15 seconds, and then touching a small plastic soda straw to the water surface, withdrawing a drop of suspension. The drop of suspension was spread over a cover slip, dried and cemented to a 25 X 75 mm glass microscope slide.

Specimens to be examined in the SEM were prepared as follows: A droplet of suspension was withdrawn from the 50 ml sample jar in the same manner as if a glass slide were being prepared. This droplet of suspension was then placed in a watch glass and diluted with distilled water until it was only slightly turbid. A 12 mm diameter circular cover slip was covered with a cushion of distilled water. One to two drops of the turbid suspension were added to the water cushion with a capillary tube. The two fluids were mixed by blowing through the tube onto the liquid-covered surface. The dried cover slips were placed on standard aluminum SEM specimen studs, circled with Elmer's glue, dried, coated with chromium in a vacuum evaporator, and viewed in the SEM.

A technique for transferring specimens observed and photographed with the light microscope to the SEM was perfected near the conclusion of this investigation. The technique involves circling located specimens on the circular cover slip which is then transferred to an SEM specimen stud. This technique is described in Sherwood and Levin, 1973.

VII. BIOSTRATIGRAPHIC RESULTS AND PALEOECOLOGICAL INTERPRETATIONS

Eighty previously described species representing 25 genera of calcareous nannofossils were identified from the Weches Formation. The relative abundance of species was determined by counting 200 specimens per slide and the results of the counts recorded as a percentage on the distribution chart (Table 1). Outcrop samples are indicated by the letter designations used on the stratigraphic sections, and well samples are indicated by their depth in feet below sea level.

A prominent limestone bed at both Burleson Bluff and Smithville was used to accurately combine outcrop sections containing the best flora into a composite stratigraphic section. Gartner's (1971) *Discoaster tani* s.l.–*Sphenolithus radians* Zone, *Reticulofenestra umbilica*–*Sphenolithus furcatolithoides* Zone, *Pemma papillatum* Zone, *Reticulofenestra* Datum and *Discoaster saipanensis* Datum were recognized and delineated within the composite stratigraphic section. The composite outcrop section is assignable to nannofossil zones NP 13 (upper) through NP 16 of Martini (1971).

As would be expected in an onlap-offlap depositional system, younger and older portions of the Weches Formation were found in downdip subsurface samples. The older portion of the formation is assignable

to Gartner's *Discoaster lodoensis* Zone and *Discoaster sublodoensis* Zone. The younger portion, indicated by the occurrence of *Chiasmolithus oamaruensis,* would have to be at least as young as the lower portion of Gartner's *Hayella situliformis* Zone. The older subsurface sediments can be assigned to the upper portion of NP 12 and NP 13 (lower). The younger subsurface sediments are assignable to Martini's NP 18.

Martini (1971) and Gartner (1971) assign somewhat different total ranges to particular Eocene guide nannofossils. As a result, age assignment of parts of the Weches differ, depending upon which scheme of zonation is utilized. The age assignment of samples in the composite stratigraphic section is based upon the first occurrences of age diagnostic species within each sample (Figure 3). The ranges of diagnostic species used in determining the age of samples are those of Gartner (1971).

Two zones indicated by Gartner as indicative of the middle Eocene (*Bramletteius serraculoides* and *Chiphragmalithus quadratus* Zones) were not found in either the surface or subsurface sections of the Weches Formation. The *Bramletteius serraculoides* Zone should have occurred between the *Pemma papillatum* Zone and *Discoaster saipanensis* Datum. The *Chiphragmalithus quadratus* Zone should have occurred between the *Discoaster tani* s.1.–*Sphenolithus radians* Zone and the *Discoaster sublodoensis* Zone.

The absence of *Bramletteius serraculoides* may be due to the preference of this species for an open-ocean paleoenvironment. Gartner (1971, p. 104) has reported the occurrence of *Bramletteius serraculoides* in pelagic oozes, and noted that it is only rarely encountered in hemipelagic sediments. The absence of the *Chiphragmalithus quadratus* Zone may be attributed either to this species preference for an open-ocean paleoenvironment, or its lack of preservation in the Weches. Erosion or nondeposition of Weches sediments representing these intervals of time may also account for the absence of these species.

The assemblage of nannofossils observed in the subsurface samples contained 13 of the 20 species suggested as indicators of shelf deposits by Bukry *et al.* (1971, pp. 1264-65). Twelve of these 20 shelf indicators were found in the outcrop samples. Therefore, all samples are considered to represent the shelf environment. The down-dip position of the subsurface samples indicates that they were deposited in deeper water than the outcrop sections whereas the occurrence of the shelf assemblage of nannofossils restricts them to the neritic environment. Thus the subsurface samples are considered to represent a deeper (outer neritic) paleoenvironment.

Variations in the occurrence and abundance of species between outcrop and subsurface samples were found to exist. These variations may be the result of differential preservation or the result of living species being restricted to particular areas of the neritic environment. The following species were found only in the subsurface portion of the Weches and are considered indicators of the outer neritic environment.

Chiasmolithus titus
Pontosphaera plana
Pontosphaera versa
Micrantholithus procerus
Sphenolithus furcatolithoides
Sphenolithus obtusus
Trochoaster radiatus
Discoaster aster
Discoaster diastypus
Discoaster triangularis
Discoaster woodringi

The following species were found to occur in several subsurface samples but appeared in only one or two outcrop samples. These species probably could live throughout the neritic environment but preferred deeper portions or were better preserved in deeper water portions.

Chiasmolithus grandis
Pontosphaera pectinata
Braarudosphaera discula
Micrantholithus flos
Micrantholithus ornatus
Helicopontosphaera lophota
Rhabdolithes rudis
Discoaster stella
Discoaster barbadiensis
Discoaster saipanensis
Discoaster tani nodifer

Lophodolithus rotundus and *Marthasterites furcatus* occurred exclusively in outcrop samples. *Chiasmolithus bidens, Blackites amplus* and *Trochoaster simplex* occurred several times in outcrop samples but each is found only once in the subsurface. These five species are considered indicative of the middle to inner neritic environment. *Cyclococcolithina formosa, Cruciplacolithus staurion,* and *Zygrhablithus bijugatus* occurred in both subsurface and surface samples but were generally present in greater abundance in subsurface samples. *Ericsonia muiri, Reticulofenestra coenura, Koczyia wechesensis, Transversopontis pulchriporus, Blackites tenuis,* and *Discoaster elegans* were present in greater abundance in outcrop samples.

The abundant occurrence of the holococcolith *Zygrhablithus bijugatus* in the slowly deposited, reworked (bioturbated) sediments of the Weches Formation suggests that the occurrence of this species in shelf environments is not necessarily a preservation artifact as suggested by Gartner and Bukry (1969). The occurrence of *Zygrhablithus bijugatus* as well as the observed lateral variations within the coccolith population may reflect a preference for nutrients provided by ocean currents, upwelling or other currently unrecognized causative factors. However, the absence of the holococcoliths *Lanternithus minutus* (*Reticulofenestra umbilica Sphenolithus furcatolithoides* Zone) and *Daktylethra punctulata* (*Pemma papillatum* Zone), reported in the Eocene Lisbon Formation of Alabama (Gartner and Bukry, 1969) may mean that *Zygrhablithus bijugatus* is just more resistant to destruction than *Lanternithus minutus* and *Daktylethra punctulata.*

The presence of several species within the Weches Formation requires the extension of their first occurrence backward in time. *Blackites amplus* was previously known from the upper Eocene and lower Oligocene, and *Cruciplacolithus tenuiforatus* was known only from the Oligocene and Miocene of North Africa and Europe prior to their discovery in the early middle Eocene portion of the Weches Formation. The presence of *Trochoaster radiatus,* previously known from Germany, marks the first occurrence of this species in North America and expands its range to include the middle and upper Eocene. The range of *Discoaster tumescens* is expanded to include the late middle Eocene to Miocene.

The ranges of *Chiasmolithus consuetus, C. solitus, C. gigas, C. expansus, C. bidens, Cruciplacolithus eminens,* and *Chiphragmalithus calathus* extended beyond their previously indicated extinction points. The upward extension of so many ranges strongly suggests reworking of these species throughout the Weches Formation probably by burrowing organisms.

The first occurrence of *Blackites amplus* near the base of the *Discoaster tani* s.l.—*Sphenolithus radians* Zone may provide an additional marker for the base of this zone. The first occurrence of *Micrantholithus ornatus* and *Discoaster tumescens* probably provide correlative horizons which are younger than but which closely approximate the *Discoaster saipanensis* Datum.

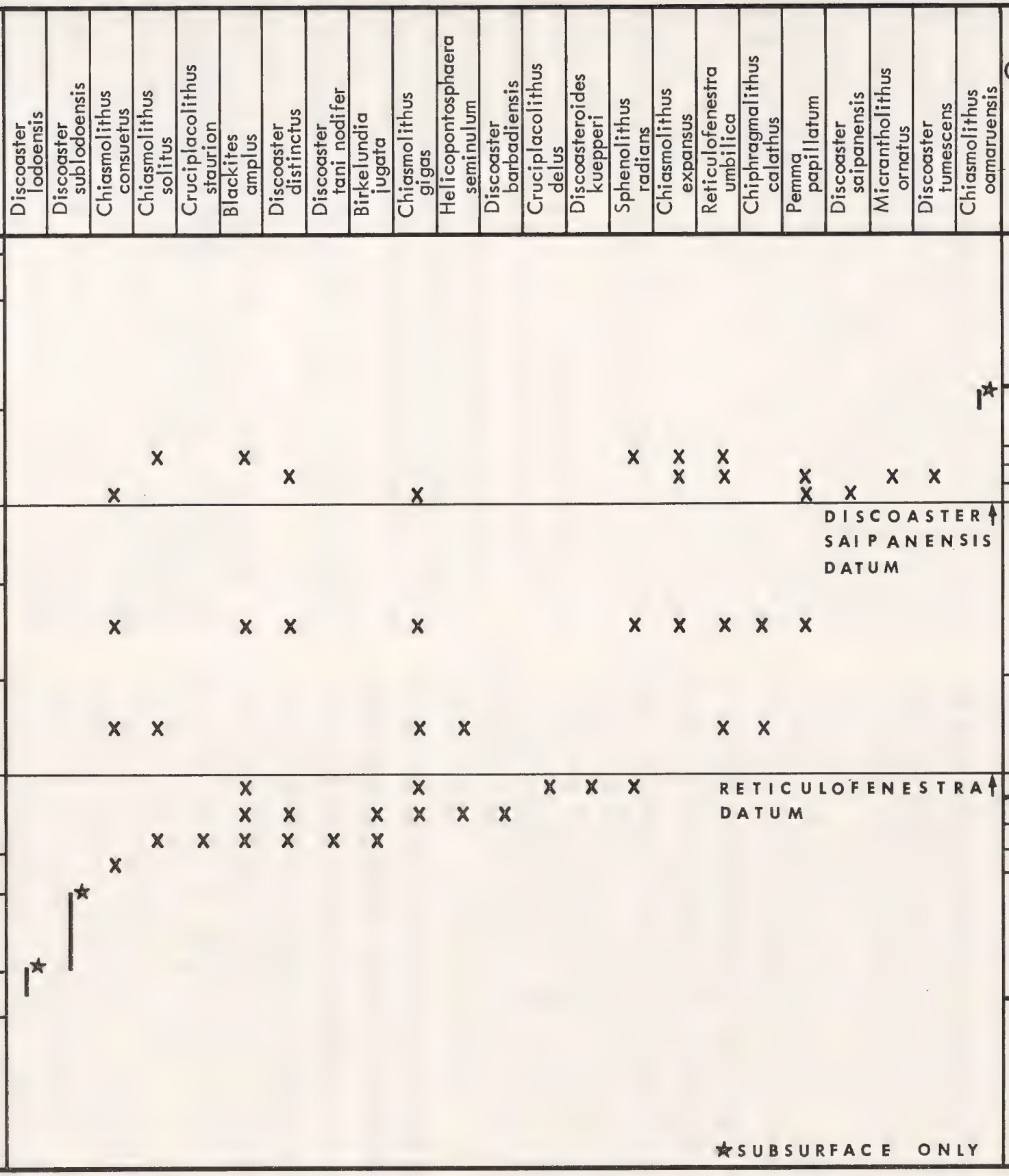
In summary, the present study supports the finer biostratigraphic divisions proposed by Gartner (1971). The stratigraphic distribution of the 80 species of nannofossils in the Weches Formation permits the recognition of five of Gartner's (1971) middle Eocene nannofossil zones and two correlative datums. In addition, the positions of two missing Eocene zones have been inferred. It is also demonstrated that variations in the distribution of calcareous nannofossils exist within the shelf environment. It is hoped that this work will encourage others to make examinations of shelf deposits for nannoplankton biofacies, and that in time assemblages indicative of discreet divisions of the shelf will be recognized and the factors controlling assemblage distribution better understood.

VIII. SYSTEMATIC PLACEMENT

Initially most paleontologists considered coccolithophorids to be animals (Protozoans) and applied rules of Zoological Nomenclature to their description and

RANGE CHART OF WECHES KEY SPECIES

AGE	PLANKTONIC FORAMINIFER ZONES (BLOW 1969)	CALCAREOUS NANNOFOSSIL ZONES (MARTINI 1971)	CALCAREOUS NANNOFOSSIL ZONES (GARTNER 1971)
EOCENE MIDDLE UPPER	P 15 Globigerapsis mexicana	NP 18 Chiasmolithus oamaruensis	Isthmolithus recurvus
		NP 17 Discoaster saipanensis	Hayella situliformis
	P 14 Truncorotaloides rohri		Helicopontosphaera compacta
		NP 16 Discoaster tani nodifer	Chiasmolithus grandis
	P 13 Orbulinoides beckmanni		Bramletteius serraculoides
	P 12 Globorotalia lehneri		Pemma papillatum
	P 11 Globigerapsis kugleri	NP 15 Chiphragmalithus alatus	Reticulofenestra umbilica Sphenolithus furcatolithoides
	P 10 Hantkenina aragonensis	NP 14 Discoaster sublodoensis	Discoaster tani s.l. Sphenolithus radians
		NP 13 Discoaster lodoensis	Chiphragmalithus quadratus
	P 9 Acaranina densa		Discoaster sublodoensis
EOCENE LOWER	P 8 Globorotalia aragonensis		Discoaster lodoensis
	P 7 Globorotalia formosa	NP 12 Marthasterites tribrachiatus	Marthasterites tribrachiatus



COMPOSITE SECTION	SAMPLES		
WECHES FORMATION	VIESCA MEMBER		H
			F
			D2
			D1
			C
	TYUS MEMBER		A
			D
			B
			A

FIGURE 3

classification. However, within the last several years many paleontologists have accepted the fact that coccoliths are algal skeletons and applied rules of Botanical Nomenclature to their descriptions and classifications. Coccolithophores are herein assigned to the Division Chrysophyta, Class Haptophyceae and the rules of Botanical Nomenclature applied.

Species of algae assigned to the Chrysophyta are distinguished from other algae by four main features. These features are: (1) The nature of the photosynthetic pigments (Chlorophyll "a" and carotenoids); (2) variability of flagellation (uniflagelate or biflagelate); (3) the type of reserve products in the cell (oil and chrysolaminarin are present; starch is never present); (4) and cell structure (a cellulose wall is absent, the outer cell membrane shows a tendency to become silicified, and endogenous cyst production is common) (Morris, 1967).

The Chrysophyta have been divided into two classes, the Haptophyceae and Chrysophyceae, according to the type of flagellation and scales found on the surface of the algal cells. Members of the Chrysophyceae have a pantonematic flagellum (longitudinal rows of hairs arranged along the axis of the flagellum) and some have a second acronematic flagellum (smooth, whip-like). The Haptophyceae have two acronematic flagella. In addition, a third appendage called a haptonema has been observed to be present in some species of the Haptophyceae. Its structure is different from that of a flagellum and it is believed to be an organ of attachment.

Both classes of algae possess species with the cell bounded only by a cytoplasmic membrane as well as species in which the cell surface is covered by a layer of scales. These scales are extremely small, being visible only with the electron microscope, and they should not be confused with the much larger coccoliths. Species having scales impregnated with silica and showing no basic type of construction have been assigned to the class Chrysophyceae. Species with scales consisting solely of organic matter and with a uniform structure have been assigned to the class Haptophyceae.

Parke (1961) summarized the evidence indicating that coccoliths belong in the class Haptophyceae. She reported that the coccolithophorids *Cricosphaera carterae, Cricosphaera sp., Pleurochrysis scherffelii* and *Coccolithus pelagicus* possess two acronematic flagella and a haptonema. She also reported that scales consisting solely of organic matter and with the uniform structure characteristic of the Haptophyceae existed on the surface of *Coccolithus pelagicus.*

IX. SYSTEMATIC PALEONTOLOGY

Kingdom PLANTAE

Class HAPTOPHYCEAE, Christensen, 1962

Unicellular flagellates which possess a haptonema.

Order PRYMNESIALES, Christensen, 1962

Motile phase with an obvious haptonema.

Family COCCOLITHACEAE Kamptner, 1928

Description: Coccolithophores bearing placoliths, proximal shield producing an interference figure, distal shield dark or faintly illuminated in two quadrants in cross-polarized light.

Genus BIRKELUNDIA Perch-Nielsen, 1971

Description: Elliptical coccoliths with a distal shield of slightly overlapping elements with a simple basal shield. The central field can be filled, empty, or bridged. This genus is distinguished from *Chiasmolithus, Cruciplacolithus, Coccolithus,* and *Ericsonia* by having a proximal shield made of a single cycle of elements which lie next to each other. The other of the above mentioned genera contain two cycles of elements in the proximal shield which are oriented in opposite directions.

Type Species: Birkelundia arenosa Perch-Nielsen

BIRKELUNDIA JUGATA (Perch-Nielsen) Perch-Nielsen, 1971

Plate 2, fig. 1

Tremalithus jugatus PERCH-NIELSEN, 1967, p. 28, pl. 4, figs. 6,7.

Birkelundia jugata (Perch-Nielsen). PERCH-NIELSEN, 1971a, p. 947, fig. 5; PERCH-NIELSEN, 1971b, p. 10, pl. 1, figs. 6-8;

Remarks: Elliptical placoliths showing in distal view an outer cycle of elements steeply inclined with respect to a raised ring which surrounds an open elliptical central area. The central area is spanned by a crossbar aligned parallel to the short axis of the ellipse. Below the level of the crossbar a shelf extends around the open central area. The rectangular elements of the ring are about 1.0 X 0.2 microns, with the longer axes radially disposed about the center of the coccolith. Forty to 50 elements make up the ring. The elements in the outer cycle are a little longer than one micron and slightly wedge-shaped. Each element of the outer cycle corresponds to an element of the raised ring.

Perch-Nielsen has designated as basal a view showing a convex surface. This seems unlikely because all other members of the Family Coccolithaceae are convex distally. The convex surface of this species is here considered as distal.

In distal view *Birkelundia jugata* is distinguished from *Coccolithus pelagicus* by the presence of the raised ring surrounding the central area. The cycle of elements surrounding the raised ring is more steeply inclined than the elements of the distal shield of *C. pelagicus*.

Hypotype: Smithville A, SEM Negative 5665; Size: 9 microns long.

Occurrence: Reported from the Eocene of Denmark.

Genus COCCOLITHUS Schwarz, 1894

Description: Elliptical placoliths, with the distal shield larger than the proximal shield. The elements of the distal shield have the crystallographic C-axes perpendicular to the plane of the shield. The observed interference figure is produced by the proximal shield and the collar. The distal shield is joined to the proximal shield by a hollow tube, and both shields are concave on their proximal sides.

Type Species: Coccolithus oceanicus Schwarz.

COCCOLITHUS EOPELAGICUS
(Bramlette and Riedel)
Bramlette and Sullivan, 1961
Plate 1, figs. 1, 2

"Coccolithus" JUKES-BROWN and HARRISON, 1892, p. 178, fig. 8.

Tremalithus eopelagicus BRAMLETTE and RIEDEL, 1954, p. 392, pl. 38, fig. 2;

Coccolithus eopelagicus (Bramlette and Riedel). BRAMLETTE and SULLIVAN, 1961, p. 141; STRADNER, 1962, p. 178; STRADNER, 1964, p. 134, text-figs. 1-2; HAY, MOHLER and WADE, 1966, p. 385, pl. 1, fig. 1; EDWARDS, 1966, p. 485, figs. 8, 11; HAQ, 1966, p. 29, pl. 1, fig. 4; pl. 1, fig. 4; pl. 5, fig. 6; BRAMLETTE and WILCOXON, 1967, p. 102, pl. 4, figs. 6–8; REINHARDT, 1967, p. 204, pl. 1, figs. 1, 2, 5, 6 *non* fig. 19; pl. 4, figs. 3, 6, 10; *non* pl. 5, figs. 1–4; *non* pl. 6, fig. 7; *non* text-figs. 3, 4; STRADNER and EDWARDS, 1968, p. 15, pl. 6, figs. 1–4; RADOMSKI, 1968, p. 564, pl. 45, figs. 5, 6; BILGÜTAY, JAFAR, STRADNER, and SZÖTS, 1969, p. 174, pl. 2, figs. 1, 2; MARTINI, 1969b, p. 131; GARTNER, 1971, figs. 4, 5.

Coccolithus aff. *C. eopelagicus* (Bramlette and Riedel). LEVIN, 1965, p. 266, pl. 41, fig. 4.

Coccolithus cf. C. *eopelagicus* (Bramlette and Riedel). LEVIN and JOERGER, 1967, p. 165, pl. 1, fig. 2; ACHUTHAN and STRADNER, 1969, p. 4, pl. 1, figs. 5–7; HAQ, 1971d, p. 19, pl. 2, fig. 7.

Remarks: Elliptical placolith with a convex distal shield made up of 50–60 elements. The distal shield is larger than the concave proximal shield. The center of this placolith bears an enlongate slit which often produces the optical illusion of two holes or depressions located at the ends of the slit.

The sutures on the distal shield are straight. The outer cycle of elements in the distal shield shows low birefringence whereas the proximal shield has high birefringence.

This species is larger than *Coccolithus pelagicus*. The central slot is generally broader and more circular than in *C. pelagicus*. The slot is more elliptical than that in *C. sarsiae*.

Hypotype: Fort Bend County 6, 9490, Photomicrograph Negatives 23-20 and 23-21; Size: 14 X 12.5 microns.

Occurrence: Known from the Paleocene to Holocene in many parts of the world.

COCCOLITHUS PELAGICUS
(Wallich) Schiller, 1930
Plate 1, figs. 3, 4
Plate 2, fig. 2

Coccosphaera pelagica WALLICH, 1877, p. 348, figs. 1, 2, 5, 11, 12.

Coccolithus pelagicus (Wallich). SCHILLER, 1930, p. 246, figs. 123, 124; DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 151, pl. 8, figs. 8–11; KAMPTNER, 1954, p. 20, figs. 14, 15; MANIVIT, 1961, p. 347, pl. 2, figs. 1–3; NARASIMHAN, 1961, p. 119, pl. 4, fig. 17; pl. 8, fig. 12; MARTINI and BRAMLETTE, 1963, p. 849; BLACK, 1963, p. 44, pl. 1, fig. 7; COHEN, 1965a, p. 12, pl. 1, figs. a–c; MARTINI, 1965, p. 402, pl. 34, figs. 1–3; HAQ, 1966, p. 31, pl. 1, fig. 5; BRAMLETTE and WILCOXON, 1967, p. 102, pl. 3, figs. 3–5; LEVIN and JOERGER, 1967, p. 165, pl. 1, figs. 4a,b; 5; MCINTYRE and BÉ, 1967, p. 569, pl. 8, figs. A–C; MCINTYRE, BÉ, and PREIKSTAS, 1967, p. 11, pl. 4, fig. A–B; REINHARDT, 1967, p. 204, pl. 1, fig. 19; pl. 4, figs. 5, 6, 10; pl. 5, figs. 1, 3; text-figs. 3, 4; RADOMSKI, 1968, p. 566, pl. 43, figs. 3, 4; BOUDREAUX and HAY, 1969, p. 256, pl. 1, figs. 1–9; CLOCCHIATTI, 1969, p. 79, pl. 3, figs. 6a, b; MARTINI, 1969a, p. 286, pl. 26, figs. 1, 2; MARTINI, 1969b, p. 131; BUKRY, 1971a, p. 965, pl. 1, figs. 1, 2. CLOCCHIATTI, 1971, p. 26, pl. 1, figs. 1–5; pl. 2, figs. 1–5; text-figs. 3, 4; PERCH-NIELSEN, 1971a, p. 947, fig. 5.

Coccolithus cf. *C. pelagicus* BOUCHÉ, 1962, p. 83, pl. 1, figs. 12, 13, 24.

Remarks: Elliptical placoliths with a convex distal shield connected to a smaller concave proximal shield. The distal shield consists of 35–45 elements redially disposed about the central area. The central area is smooth showing no striae. It contains an elliptical opening spanned by a crossbar on the proximal shield which is aligned with the short axis of the ellipse. The crossbar is not always present. The C-axis of the elements in the distal shield is oriented nearly perpendicular to the plane of the shield. This results in low birefringence seen in the distal shields. Sutures may be seen to curve counterclockwise near the periphery of the distal shield.

The central area makes up a smaller portion of the distal shield in this species than in *Coccolithus eopelagicus*. *C. eopelagicus* is more circular than *C. pelagicus*. Both species show low birefringence in the outer cycle of elements and high birefringence in the central area.

Hypotypes: Hurricane Shoals M (26.3; 68.0); W.U.M.C. 000204; Size: 15 X 12.5 microns. Smithville A , SEM Negative 4871; Size: 7 X 5 microns.

Occurrence : World-wide throughout the Cenozoic with greatest abundance in the upper Cenozoic.

COCCOLITHUS SARSIAE Black, 1962

Plate 1, figs. 5, 6, 7
Plate 2, fig. 3

Coccolithus sarsiae BLACK, 1962, p. 125, pl. 8, fig. 2; pl. 9, figs. 2–6; HAY, MOHLER and WADE, 1966, pl. 1, figs. 2–5; CLOCCHIATTI, 1971, p. 31, pl. 3, fig. 2.

Coccolithus sp. cf. *C. sarsiae* BLACK, pl. 451, fig. 6.

Coccolithus pelagicus REINHARDT, 1967, p. 204, pl. 5, figs. 2, 4; pl. 6, fig. 7.

Remarks: Elliptical placoliths with 36–45 radially arranged elements in the outer cycle of the distal shield. The central area is composed of granular elements and occupies less than one-half the width of the distal shield. An elliptical opening perforates the central area. The convex distal shield is larger than the concave proximal shield. The distal shield shows low birefringence in cross-polarized light.

The central area of this species is more prominent in phase-contrast illumination than the central areas of *C. pelagicus* or *C. eopelagicus*. The ends of the elliptical central perforation are rounded, giving it a slit-like appearance. The figured specimens of *C. pelagicus* from Reinhardt (1967), have been referred to this taxon on the basis of a similar number of elements in the distal shield.

Hypotypes: Smithville A (10.7; 76.7), W.U.M.C. 000205; Size: 10X 7.5 microns. SEM Negative 5693; Size: 8.2 x 7.8 microns.

Occurrence: This species has been reported from the upper Eocene of Nal'chik Southwestern U.S.S.R.; a Tertiary outcrop on the continental slope off Brittany; and the Oligocene of Odder, Denmark.

COCCOLITHUS sp.

Remarks: Placoliths in the size range of 5–8 microns which could not be assigned to other taxa of this genus have been placed here. These specimens may be round, subcircular, or elliptical and differ from the identified species of this genus in the size and shape of their central area, the width of the outer cycle of elements in the distal shield or in the nature of their interference pattern. This entry is made to provide a quantitative evaluation of forms not assignable to described species of this genus.

Genus CHIASMOLITHUS
Hay, Mohler, and Wade, 1966

Description: Placoliths with a prominent central opening spanned by an X-shaped structure. Distal rim wider than proximal rim.

Type Species:Chiasmolithus oamaruensis (Deflandre) Hay, Mohler and Wade.

CHIASMOLITHUS BIDENS
(Bramlette and Sullivan)
Hay and Mohler, 1967
Plate 1, figs. 8, 9, 10
Plate 2, figs. 4, 5

Coccolithus bidens BRAMLETTE AND SULLIVAN, 1961, p. 139, pl. 1, fig. 1; SULLIVAN, 1964, p. 180, pl. 1, fig. 10; SULLIVAN, 1965, p. 131; EDWARDS, 1966, figs. 2, 5.

Chiasmolithus bidens (Bramlette and Sullivan). HAY and MOHLER, 1967, p. 1526, pl. 196, figs. 23–25; *non* figs. 14, 15, 16; pl. 197, figs. 4, 9, 14; RADOMSKI, 1968, p. 558, pl. 44, figs. 5, 6; GARTNER, 1970, p. 941, fig. 7; GARTNER, 1971, figs. 3–5; HAQ, 1971a, p. 15, pl. 3, fig. 3; PERCH-NIELSEN, 1971a, p. 947, fig. 6.

Remarks: Elliptical placoliths with a steeply slanting, narrow outer cycle of approximately 60 elements and a wider smooth inner cycle of elements on the distal shield. The distal shield is larger than the proximal shield and has a large central opening spanned by a modified X-shaped crossbar. The crossbar shows an axial line in transmitted light and in cross-polarized light. The distal surface of the crossbar is made up of calcite laths with their long axes aligned parallel to the axis of the crossbar segments. The crossbar consists of one nearly straight segment abutted by two shorter segments.

SEM micrographs show the proximal disc to be smoothly textured. However, the surface of the tube which joins the proximal and distal discs is lined with a reticulate network of calcite elements. This network of calcite elements extends upward onto the underside of the distal disc covering the proximal surface of the crossbar and the open interareas. Stefan Gartner, Jr., suggested, in his review of the manuscript, that the figured specimen is *C. solitus.*

Hypotypes: Sabine River E (23.1; 68.4), W.U.M.C. 000206; Size: 10 X 8 microns. SEM Negative 5121; Size: 10 microns longs. SEM Negative 5135; Size: 13 microns long.

Occurrence: Reported from the middle Paleocene into the lower Eocene. In the Weches Formation it was found to exist near the middle Eocene-upper Eocene boundary with *C. oamaruensis.*

CHIASMOLITHUS CONSUETUS
(Bramlette and Sullivan)
Hay and Mohler, 1967
Plate 1, figs. 11, 12
Plate 2, fig. 6

Coccolithus consuetus BRAMLETTE and SULLIVAN, 1961, p. 139, pl. 1, fig. 2; BOUCHÉ, 1962, p. 83, pl. 1, fig. 18; SULLIVAN, 1964, p. 180, pl. 3, fig. 1; SULLIVAN, 1965, p. 31; REINHARDT, 1967, p. 206, pl. 2, figs. 14, 18; *non* pl. 1, figs. 12, 15, 16, 20; *non* pl. 2, figs. 13, 15, 17, 19; HAY, MOHLER and WADE, 1966, p. 388; GARTNER, 1971, figs. 1, 3–5.

Chiasmolithus consuetus (Bramlette and Sullivan). HAY and MOHLER, 1967, p. 1526, pl. 198, fig. 16; *non* pl. 196, figs. 23, 24, 25; RADOMSKI, 1968, pl. 45, figs. 11, 12; BILGÜTAY *et al.* 1969, p. 174, pl. 2, fig. 5; HAQ, 1971, p. 15, pl. 3, figs. 6, 7; PERCH-NIELSEN, 1971a, p. 947, fig. 6.

Chiasmolithus bidens (Bramlette and Sullivan). HAY and MOHLER, 1967, pl. 196, figs. 14, 15, 17.

Chiasmolithus danicus (Brotzen). HAY and MOHLER, 1967, pl. 198, figs. 12, 13; PERCH-NIELSEN, 1971, p. 951, fig. 6.

PLATE 1

The long axis of each specimen is parallel to
the polarizer unless otherwise specified.

Magnification 1800 X

Figures Page

1, 2 *Coccolithus eopelagicus*(Bramlette and Riedel) Kamptner 13
Distal view, from Fort Bend County 6, 9490.

1. Phase-contrast, Photomicrograph negative 23–20.
2. Between crossed-polarizers, Photomicrograph negative 23–21.

3, 4 *Coccolithus pelagicus* (Wallich) Schiller 13
Distal view, from Hurricane Shoals M (26.3; 68.0), W.U.M.C. 000204.

3. Phase-contrast
4. Between crossed-polarizers

5–7 *Coccolithus sarsiae* Black 14
Distal view, from Smithville A (10.7; 76.7), W.U.M.C. 000205.

5. Phase-contrast, 45 degrees to polarizer
6. Between crossed-polarizers, 45 degrees to polarizer
7. Between crossed-polarizers

8–10 *Chiasmolithus bidens* (Bramlette and Sullivan) Hay and Mohler 15
Distal view, from Sabine River 3 (23.1; 68.4), W.U.M.C. 000206.

8. Phase-contrast
9. Phase-contrast, 21 degrees counterclockwise from polarizer
10. Between crossed-polarizers, 21 degrees counterclockwise from polarizer

11, 12 *Chiasmolithus consuetus* (Bramlette and Sullivan) Hay and Mohler 15
Distal view, from Hurricane Shoals J (10.4; 71.2), W.U.M.C. 000207.

11. Phase-contrast
12. Between crossed-polarizers

13, 14 *Chiasmolithus expansus* (Bramlette and Sullivan) Gartner 18
Distal view, from Hurricane Shoals M (24.3; 74.2), W.U.M.C. 000208.

13. Phase-contrast
14. Between crossed-polarizers

15, 16 *Chiasmolithus solitus* (Bramlette and Sullivan) Locker 20
Distal view, from Smithville C (16.8; 75.5), W.U.M.C. 000211.

15. Phase-contrast, parallel to analyzer
16. Between crossed-polarizers

(continued next page)

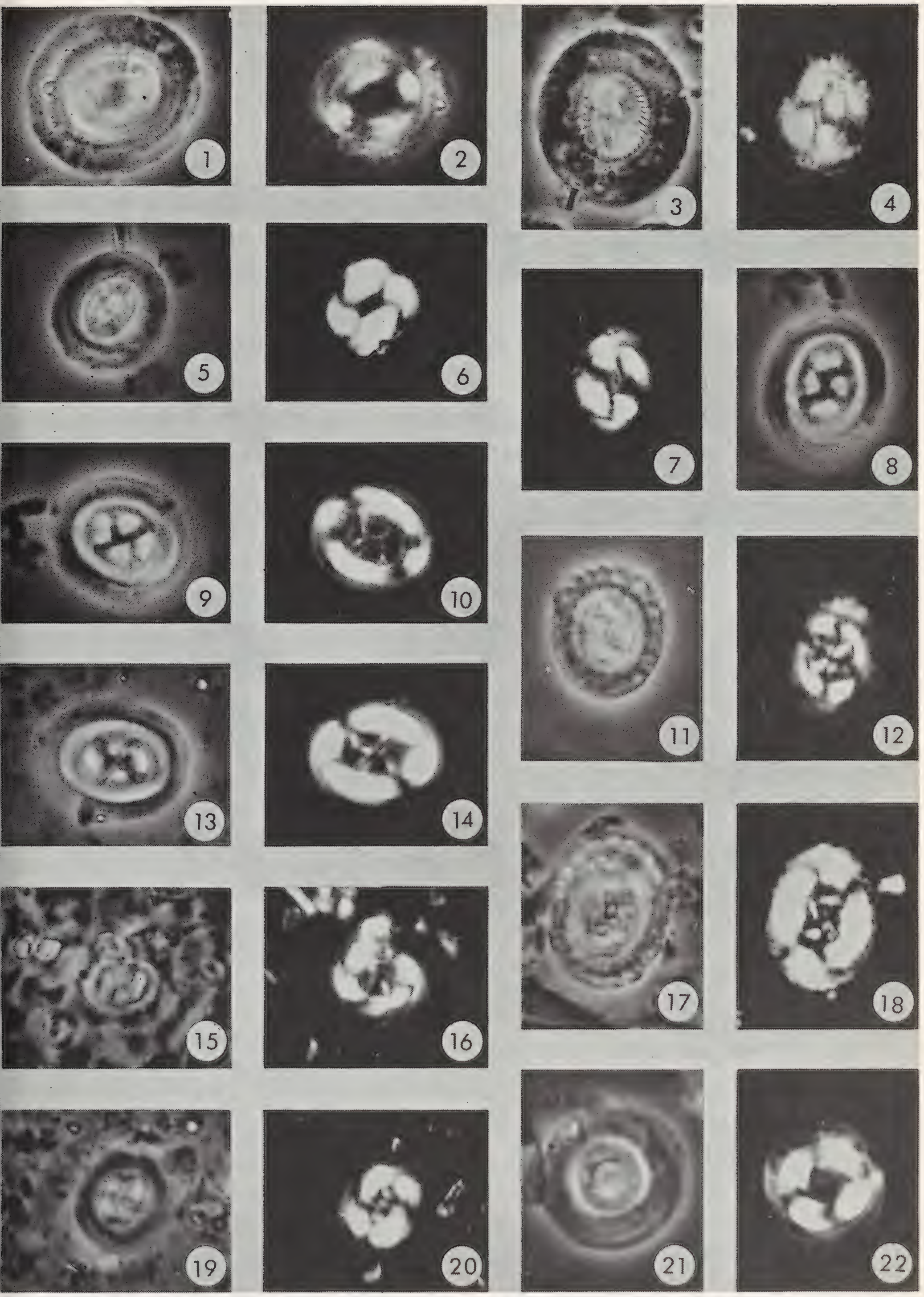


PLATE 1

17, 18 *Chiasmolithus gigas* (Bramlette and Sullivan) Gartner 19
Distal view, from Smithville D_2 (07.4; 75.3), W.U.M.C. 000209.

17. Phase-contrast
18. Between crossed-polarizers

19, 20 *Chiasmolithus titus* Gartner 20
Distal view, from Hardin County 11, 8148 (28.6; 75.0), W.U.M.C. 000212.

19. Phase-contrast
20. Between crossed-polarizers

21, 22 *Cyclococcolithina formosa* (Kamptner) Wilcoxon 24
Distal view, from Fort Bend County 6, 10180 (07.7; 73.8), W.U.M.C. 000216.

21. Phase-contrast
22. Between crossed-polarizers

Remarks: Elliptical placoliths with an X-shaped crossbar spanning and largely filling a small open central area. The distal shield has a wide, steeply sloping outer cycle of 38–42 tabular elements. The sutures between elements are directed radially from the center of the placolith. The inner cycle of elements around the central opening is quite narrow. The crossbar shows no axial lines in transmitted light or in cross-polarized light.

Hypotypes: Hurricane Shoals J (10.4; 71.2), W.U.M.C. 000207; Size: 10 X 9 microns. Fort Bend County 6,9490, SEM negative 5795; Size: 9 X 7.5 microns.

Occurrence: Reported from the Paleocene (Danian) to the middle Eocene of various parts of the world.

CHIASMOLITHUS EXPANSUS
(Bramlette and Sullivan)
Gartner, 1970
Plate 1, figs. 13, 14

Coccolithus expansus BRAMLETTE and SULLIVAN, 1961, p. 139, pl. 1, fig. 5; SULLIVAN, 1965, p. 32, pl. 2, fig. 5; HAY, MOHLER and WADE, 1966, p. 388.

Chiasmolithus expansus (Bramlette and Sullivan). GARTNER, 1970, p. 943, fig. 11–1, 2; GARTNER, 1971, figs. 4, 5; PERCH-NIELSEN, 1971a, p. 947, fig. 6; PERCH-NIELSEN, 1971b, p. 17, pl. 10, figs. 1–3; pl. 11, fig. 5; pl. 60, figs. 9, 10.

?Chiasmolithus aff. *C. expansus* (Bramlette and Sullivan). HAQ, 1971c, p. 109, pl. 11, figs. 10, 11.

Remarks: Elliptical placoliths with a large central opening spanned by an H-shaped crossbar. The outer and inner cycle of elements of the distal shield are relatively narrow with the outer cycle being the widest. The distal shield is larger than the proximal shield. The crossbar is arched slightly above the plane of the distal shield. In transmitted light and in cross-polarized light, an axial line is present along the crossbars.

Forms of this species encountered in the Weches Formation are somewhat smaller than those generally reported in the literature. The outer cycle of elements of the distal shield is also wider than most figured specimens. However, the shape of the crossbar and the appearance of the axial line are definitely that of *C. expansus* as figured by Gartner (1970). Stefan Gartner, Jr., suggested that the figured specimen is *C. solitus* in his review of the manuscript.

Hypotype: Hurricane Shoals M (24.3; 74.2) W.U.M.C. 000208; Size: 12 X 10 microns.

Occurrence: Reported from the lower and middle Eocene in various parts of the world.

CHIASMOLITHUS GIGAS
(Bramlette and Sullivan)
Radomski, 1968
Plate 1, figs. 17, 18
Plate 2, fig. 7

Coccolithus gigas BRAMLETTE and SULLIVAN, 1961, p. 140, pl. 1, fig. 6; SULLIVAN, 1965, p. 32, pl. 2, fig. 6; HAY, MOHLER, and WADE, 1966, p. 388; BYSTRICKÁ, 1969b, pl. 16, figs. 7–10.

Chiasmolithus gigas (Bramlette and Sullivan). RADOMSKI, 1968, p. 559, pl. 44, figs. 1, 2; GARTNER, 1970, p. 943, figs. 12, 13a, b, c; GARTNER, 1971, figs. 1, 4, 5; PERCH-NIELSEN, 1971a, p. 947, fig. 6; ROTH, BAUMANN, and BERTOLINO, 1971, figs. 5, 7.

Chiasmolithus cf. *C. gigas* (Bramlette and Sullivan). PERCH-NIELSEN, 1971b, p. 17, pl. 14, fig. 7.

Remarks: Large elliptical placoliths with a modified H-shaped crossbar spanning a small open central area. The distal shield has a wide nearly flat outer cycle of 36–40 wedge-shaped elements surrounding a narrow inner cycle of 32–36 rectangular elements. The distal shield is larger than the proximal shield. The crossbar does not show an axial suture or axial line in transmitted light or in cross-polarized light, contrary to Gartner's 1970 report. SEM micrographs show the crossbar to be made of robust laths with their axes aligned parallel to the axes of the crossbar segments. Stefan Gartner, Jr., questioned the identification of this species in his review of the manuscript.

Hypotypes: Smithville D_2 (07.4; 75.3), W.U.M.C. 000209; Size: 12.5 X 10 microns. SEM negative 1; Size: 9.5 X 7.5 microns.

Occurrence: Reported from the middle Eocene in various parts of the world.

CHIASMOLITHUS GRANDIS
(Bramlette and Riedel)
Radomski, 1968
Plate 3, figs. 1, 2

Coccolithus cretaceus, Arkhangelsky. DEFLANDRE *in* GRASSÉ, 1952, p. 463, text-fig. 360d.

Coccolithus grandis BRAMLETTE and RIEDEL, 1954, p. 391, pl. 38, figs. 1a–b; DEFLANDRE and FERT, 1954, p. 152, text-fig. 48; BRAMLETTE and SULLIVAN, 1961, p. 140, pl. 2, figs. 1a–b, 2a–c, 3; NARASIMHAN, 1961, pl. 4, fig. 13; pl. 8, fig. 10; HAY, MOHLER and WADE, 1966, p. 388.

Chiasmolithus grandis (Bramlette and Riedel). RADOMSKI, 1968, p. 560, pl. 44, figs. 3, 4; BILGÜTAY *et al.*, 1969, p. 173, pl. 2, figs. 3, 4; GARTNER, 1970, p. 944, figs. 11–3, 14; GARTNER, 1971, figs. 1, 2, 4, 5; MARTINI, 1971c, p. 743; PERCH-NIELSEN, 1971a, p. 947, fig. 6; PERCH-NIELSEN, 1971b, p. 18, pl. 9, figs. 1, 3; pl. 10, fig. 4; pl. 60, figs. 1, 2; ROTH, BAUMANN, BERTOLINO,1971, figs. 5, 7.

Remarks: Large elliptical placoliths with a modified H-shaped crossbar spanning a large open central area. The distal shield has a steep, slightly convex outer slope, a narrow smooth inner slope and is larger than the proximal shield. The crossbar bears an axial suture in transmitted light and has one to several closely spaced dark parallel axial lines in cross-polarized light. Tooth-like projections extend into the interareas between crossbars from the smooth inner slope of the distal shield on all specimens.

Hypotype: Smithville A (07.2; 70.1), W.U.M.C. 000210; Size: 20 X 15 microns.

Occurrence: Reported from the lower and middle Eocene in various parts of the world.

CHIASMOLITHUS OAMARUENSIS
(Deflandre)
Hay, Mohler, and Wade, 1966
Plate 2, fig. 8

Tremalithus oamaruensis DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 154, pl. 11, fig. 22; text-figs. 72–74.

Coccolithus oamaruensis (Deflandre). LEVIN, 1965, p. 265, pl. 41, fig. 3; LEVIN and JOERGER, 1967, p. 165, pl. 1, figs. 6a–b.

Chiasmolithus oamaruensis (Deflandre). HAY, MOHLER and WADE, 1966, p. 388, pl 7, fig. 1; STRADNER and EDWARDS, 1968, p. 13, pl. 1–5; RADOMSKI, 1968, p. 560; GARTNER, 1971, figs. 4, 5; HAQ, 1971c, p. 108, pl. 11, fig. 9; pl. 12, figs. 6–9; pl. 15, fig. 6; PERCH-NIELSEN, 1971a, p. 947, fig. 6; PERCH-NIELSEN, 1971b, p. 20, pl. 14, fig. 6; pl. 60, figs. 11, 12; ROTH, BAUMANN, BERTOLINO, 1971, figs. 5–9.

Remarks: Elliptical placoliths with a narrow, steeply sloping outer cycle of 65–75 elements. The sutures between elements are inclined slightly clockwise. The inner cycle of elements is wider and composed of indistinct crystallites which appear to be narrower than those in the outer cycle. The moderately large open central area is spanned by a nearly perfect X-shaped crossbar. The crossbar is only slightly arched and shows an axial line in transmitted light and cross-polarized light. The distal shield is larger than the proximal shield. Stefan Gartner, Jr., questioned the identification of this species in his review of the manuscript.

Hypotype: Liberty County 12, 10210, SEM negative 6482; Size: 9 X 7 microns.

Occurrence: Reported from the upper Eocene into the lower Oligocene in various parts of the world.

CHIASMOLITHUS SOLITUS
(Bramlette and Sullivan)
Locker, 1968
Plate 1, figs. 15, 16

Coccolithus solitus BRAMLETTE and SULLIVAN, 1961, p. 140, pl. 2, fig. 4; SULLIVAN, 1964, p. 181, pl. 1, fig. 13; SULLIVAN, 1965, p. 32; HAY, MOHLER and WADE, 1966, p. 388; RADOMSKI, 1968, p. 560, pl. 45, figs. 13, 14; PERCH-NIELSEN, 1971a, p. 947, fig. 6.

Chiasmolithus solitus (Bramlette and Sullivan). LOCKER, 1968, pp. 221, 222, 227, pl. 1, figs. 5, 6; PERCH-NIELSEN, 1971b, pl. 11, fig. 1; pl. 12, figs. 1-5; pl. 13, fig. 5; pl. 14, fig. 11; pl. 60, figs. 19, 20.

Remarks: Elliptical placoliths with the outer and inner cycle of elements in the distal shield nearly equal in width. The large open central area is spanned by a delicate X-shaped crossbar. The crossbar does not always bear an axial line in transmitted light or in cross-polarized light.

This species is variable in its appearance. In some forms the outer cycle of elements is wider than the inner cycle and vice versa. The crossbar generally formed a nearly perfect "X" but sometimes two shorter segments are offset along one long straight segment. The forms encountered in the Weches Formation ranged between those figured by Bramlette and Sullivan (1961) and Gartner (1970).

Hypotype: Smithville C (16.8; 75.5), W.U.M.C. 000211; Size: 14 X 9.5 microns.

Occurrence: Reported from the lower and middle Eocene in various parts of the world.

CHIASMOLITHUS TITUS
Gartner, 1970
Plate 1, figs. 19, 20

Coccolithus consuetus Bramlette and Sullivan. LEVIN and JOERGER, 1967, p. 164, pl. 1, figs. 1a–b; *non* BRAMLETTE and SULLIVAN, 1961; PERCH-NIELSEN, 1971a, p. 947, fig. 6.

Chiasmolithus titus GARTNER, 1970, p. 945, fig. 17; GARTNER, 1971, figs. 1, 4, 5.

Remarks: Elliptical placoliths with the outer cycle of elements of the distal shield wider than the inner cycle. A small central opening is present in the distal shield and is spanned by an X-shaped crossbar. One segment of the crossbar is straight; the other S-shaped. The ends of the "S" are parallel to the short axis of the ellipse whereas the middle is parallel to the long axis. The crossbar does not bear an axial line in transmitted light or in cross-polarized light.

The S-shaped crossbar is distinctive and is the sole consistent distinguishing feature of this species.

Hypotype: Hardin County 11, 8148 (28.6; 75.0), W.U.M.C. 000212; Size: 9 X 7 microns.

Occurrence: Reported from the middle and upper Eocene of the Gulf Coast area of the United States, where it is particularly well developed in the Shubuta Member of the Yazoo Clay in Mississippi and the Lisbon Formation at Little Stave Creek, Alabama.

Genus CRUCIPLACOLITHUS
Hay and Mohler, 1967
Synonym: Crucilithus
Stradner, 1968.

Description: Concave elliptical placoliths with a central cross, having arms oriented in the major and minor axes of the open elliptical central area.

Type Species: Cruciplacolithus tenuis (Stradner) Hay and Mohler.

CRUCIPLACOLITHUS DELUS
(Bramlette and Sullivan)
Perch-Nielsen, 1971
Plate 3, figs. 7–10
Plate 2, figs. 9, 10

Coccolithites delus BRAMLETTE and SULLIVAN, 1961, p. 151, pl. 7, figs. 1,2; SULLIVAN, 1964, p. 180, pl. 1, figs. 8, 9; SULLIVAN, 1965, p. 31.

Cyathosphaera crux (Deflandre). HAY and TOWE, 1962, p. 507, pl. 2, fig. 1.

Coccolithus delus (Bramlette and Sullivan). PERCH-NIELSEN, 1967, p. 22, pl. 1, figs. 1–3.

Campylosphaera dela (Bramlette and Sullivan). HAY and MOHLER, 1967, p. 1531, pl. 198, fig. 14; BUKRY and KENNEDY, 1969, fig. 3, no. 1; GARTNER, 1971, figs. 3–5.

Cruciplacolithus delus (Bramlette and Sullivan). PERCH-NIELSEN, 1971a, p. 947, fig. 7; PERCH-NIELSEN, 1971b, p. 22, pl. 13, figs. 7, 8.

Remarks: Strongly arched elliptical placolith with a large open central area spanned by a crossbar. The arms of the crossbar are aligned parallel to the major and minor axes of the ellipse. The distal shield is strongly convex and only slightly larger than the proximal shield. The distal shield is composed of an outer cycle of approximately 60 dextrally imbricate tabular elements which are steeply inclined relative to the innermost cycle of elements. The nature of this inner cycle of elements could not be determined from the SEM micrographs available.

The proximal shield is strongly arched and composed of two or possibly three cycles of crystal elements. The crossbar is 0.8 microns across and is attached to the proximal shield. When viewed in transmitted light or in phase-contrast illumination the specimen appears rectangular in distal view and sub-elliptical in proximal view.

C. delus cannot be placed in the genus *Campylosphaera* because Kamptner (1963, p. 151) states in the description of this genus that "Eine proximale (basale) Randscheibe ist nicht verhanden." (A proximal basal rim disc is not present.) SEM micrographs show that a proximal shield is definitely present in this species.

The rectangular appearance, the large open central area, and the rather narrow distal shield serve to distinguish this species from other members of the genus encountered in the Weches Formation.

Hypotypes: Sabine River E (24.1; 79.4), W.U.M.C. 000213, Size: 8X 6 microns. SEM negative 6470; Size: 8.5 microns long. Austin County 5, 8968, SEM negative 5557; Size: 9.5 microns long.

Occurrence: Reported from the Paleocene to middle Eocene of California, the middle Eocene of Donzacq, France, and the lower Eocene of Pakistan.

CRUCIPLACOLITHUS EMINENS
(Bramlette and Sullivan)
Hay and Mohler, 1967
Plate 2, fig. 11

Coccolithus eminens BRAMLETTE and SULLIVAN, 1961, p. 139, pl. 1, fig. 3; SULLIVAN, 1964, p. 181, pl. 1, figs. 11, 12; SULLIVAN, 1965, p. 31.

Cruciplacolithus eminens (Bramlette and Sullivan). HAY and MOHLER, 1967, p. 1527, pl. 196, figs. 26–28; pl. 198, figs. 9, 10.

?Cruciplacolithus aff. *C. eminens* (Bramlette and Sullivan). HAQ, 1971c, p. 109, pl. 20, fig. 5.

Remarks: Subcircular to elliptical placoliths, concave on the proximal side and convex on the distal side. The elements on the distal shield are strongly sloping. The central opening is large relative to the overall size of the distal shield. The proximal shield is only slightly smaller than the distal shield. The crossbar is attached to the proximal shield and is aligned with an arm parallel to each axis of the ellipse.

C. eminens is distinguished from *C. staurion* by its smaller size, from *C. tenuiforatus* by its larger central opening and from *C. delus* by being more elliptical and less strongly arched. It has been suggested that this specimen belongs in the genus *Toweius*. However, there is no evidence of a reticulate grill in the central area as is characteristic of *Toweius*.

Hypotype: Smithville D_2, SEM negative 5815; Size : 7 X 6 microns.

Occurrence: Reported from the Paleocene of California, Alabama, and France.

CRUCIPLACOLITHUS STAURION
(Bramlette and Sullivan)
Gartner, 1971
Plate 3, figs. 5, 6

Coccolithus staurion BRAMLETTE and SULLIVAN, 1961, p. 141, pl. 2, figs. 5, 6; SULLIVAN, 1964, p. 181, pl. 3, figs. 2, 3; SULLIVAN, 1965, p. 32, pl. 3, fig. 7.

Cruciplacolithus staurion PERCH-NIELSEN, 1971a, p. 947, fig. 7 (transfer invalid).

Cruciplacolithus staurion (Bramlette and Sullivan). GARTNER, 1971, p. 109, fig. 4.

Birkelundia staurion (Bramlette and Sullivan). PERCH-NIELSEN, 1971b, p. 11, pl. 15, figs. 1, 3–6; pl. 61, figs. 16, 17.

Remarks: Large subcircular placolith with a large central opening spanned by a central cross. Approximately 60 elements, separated by straight sutures, are visible in the distal shield under phase-contrast illumination. The placolith is not strongly arched. The distal shield is larger than the proximal shield. The outer cycle of elements of the distal shield is much wider than the inner cycle.

PLATE 2

Magnification 4500 X

Figures — Page

1 *Birkelundia jugata* (Perch-Nielsen) Perch-Nielsen 12
Distal view, from Smithville A, SEM negative 5665.

2 *Coccolithus pelagicus* (Wallich) Schiller 13
Proximal view, from Smithville A, SEM negative 4871.

3 *Coccolithus sarsiae* Black 14
Distal view, from Smithville A, SEM negative 5693.

4, 5 *Chiasmolithus bidens* (Bramlette and Sullivan) Hay and Mohler 15
From Sabine River E.

4. Proximal view, SEM negative 5121.
5. Distal view, SEM negative 5135.

6 *Chiasmolithus consuetus* (Bramlette and Sullivan) Hay and Mohler 15
Distal view, from Fort Bend County 6, 9490, SEM negative 5795.

7 *Chiasmolithus gigas* (Bramlette and Sullivan) Gartner 19
Distal view, from Smithville D 2, SEM negative 1.

8 *Chiasmolithus oamaruensis* (Deflandre) Hay, Mohler, and Wade 19
Distal view, from Liberty County 12, 10210, SEM negative 6482.

9, 10 *Cruciplacolithus delus* (Bramlette and Sullivan) Perch-Nielsen 21

9. Proximal view, from Austin County 5, 8968, SEM negative 5557.
10. Distal view, from Sabine River E, SEM negative 6470.

11 *Cruciplacolithus eminens* (Bramlette and Sullivan) Hay and Mohler 21
Proximal view, from Smithville D_2, SEM negative 5815.

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PLATE 2

This species is distinguished by its large size and large central opening from the other members of this genus. However, many of the individuals of this species range down to 10 microns. These are distinguished from *C. tenuiforatus* by a wider crossbar and larger central opening.

Hypotype: Hurricane Shoals 205 M (17.9; 76.8), W.U.M.C. 000214; Size: 18.5 X 15 microns.

Occurrence: Reported from the lower and middle Eocene of California.

CRUCIPLACOLITHUS TENUIFORATUS
Clocchiatti and Jerkovic, 1970
Plate 3, figs. 17, 18
Plate 4, fig. 1

Cruciplacolithus tenuiforatus CLOCCHIATTI and JERKOVIĆ, 1970, p. 2, pl. 1, figs. 1–3; pl. 2, figs. 1–6; CLOCCHIATTI, 1971, p. 31, pl. 7, figs. 2–4; HAQ, 1971b, p. 80, pl. 10; fig. 11; HAQ, 1971c, p. 109, pl. 15, figs. 1, ?2, 5; PERCH-NIELSEN, 1971 a, p. 947, fig. 5.

Remarks: Subcircular to elliptical placoliths, concave on the proximal and convex on the distal side with a small central opening similar in size to that of *Coccolithus pelagicus*. The central opening is spanned by a cross attached to the proximal end of the central tube. The placolith is not strongly arched but elements of the distal shield are steeply inclined to the periphery.

This species is distinguished from *C. staurion* by its smaller overall size (9 X 10 microns versus 14 X 18 microns). The general size is the same as that of *C. eminens* but the central opening is much larger in *C. eminens*. The width of the crossbars is about the same in *C. eminens* and *C. tenuiforatus*, being less than 0.5 micron. In *C. staurion* and *C. delus* the crossbar is closer to 0.8 micron wide.

Hypotypes: Hurricane Shoals 205 M (21.95; 74.35), W.U.M.C. 000215; Size: 9 X 10 microns. Smithville D_2, SEM negative 5818; Size: 9 X 10 microns.

Occurrence: Reported from the upper Miocene in Yogoslavia and Algeria and the Oligocene of Syria and Western Germany

Genus CYCLOCOCCOLITHINA
(Kamptner)
Wilcoxon, 1970

Description: Circular placoliths having a circular central perforation.

Type Species: Cyclococcolithina leptopora (Murray and Blackman) Wilcoxon.

CYCLOCOCCOLITHINA FORMOSA
(Kamptner)
Wilcoxon, 1970
Plate 1, figs. 21, 22
Plate 4, fig. 2

Cyclococcolithus formosus KAMPTNER, 1963, p. 163, pl. 2, fig. 8, text-fig. 20; REINHARDT, 1966, p. 22, pl. 21, fig. 8; REINHARDT, 1967, p. 209, pl. 1, figs. 3, 4, 7, 8; pl. 6, figs. 3, 6; text-fig. 11; RADOMSKI, 1968, p. 568, pl. 44, figs. 7, 8; MARTINI, 1969b, p. 132, pl. 1, figs. 1, 2; ROTH, 1970, p. 854; MARTINI, 1971c, p. 743, pl. 3, figs. 1, 2; ROTH, BAUMANN, BERTOLINO, 1971, figs. 6–9.

Cyclococcolithus cf. *formosus* Kamptner. COHEN, 1965, p. 26, pl. 2, figs. a–g; *non* pl. 19, figs. c–e.

Coccolithus aff. *C. eopelagicus* (Bramlette and Riedel). LEVIN, 1965, p. 266, pl. 41, fig. 5; *non* fig. 4.

Coccolithus lusitanicus BLACK, 1964, p. 308, pl. 50, figs. 1, 2.

Cyclococcolithus lusitanicus (Black). HAY, MOHLER and WADE, 1966, p. 390, pl. 7, figs. 3–6; BRAMLETTE and WILCOXON, 1967, p. 103, pl. 3, figs. 16, 17; BUKRY and KENNEDY, 1969, p. 42, fig. 3, no. 5.

Cyclococcolithus orbis GARTNER and SMITH, 1967, p. 4, pl. 4, figs. 1–3.

Umbilicosphaera formosa (Kamptner). REINHARDT *in* COHEN and REINHARDT, 1968, p. 295.

Cyclococcolithina formosa (Kamptner). WILCOXON, 1970, p. 82; GARTNER, 1971, p. 109, figs. 1, 4, 5.

Remarks: Circular placoliths with the distal shield larger than the proximal shield. Thirty-nine to 45 sinistrally imbricate elements make up the distal shield. Each element has a flat surface and terminates peripherally in a gently rounded surface. Clockwise inclined sutures are prominent

near the periphery but fade closer to the central collar. The central collar consists of 20 gently tapered, radially disposed elements which widen distally. Between each of these elements are more strongly wedge-shaped elements which are from five to nine-tenths the length of the adjacent elements. The total number of elements in the central collar is usually equal to the number of elements in the distal shield. The line of contact between the central collar and the surrounding cycle of elements of the distal shield is serrated.

The diameter of the central collar is equal to about 60 percent of the diameter of the distal shield. In cross-polarized light a very distinct swastika-like interference figure is observed. The central collar appears to make up less than 50 percent of the diameter of the placolith when observed under phase contrast illumination.

Forms of this species found in the Weches Formation appear similar to Black's (1964) electronmicrographs and the light and electronmicrographs of Gartner and Smith (1967) and Hay, Mohler and Wade (1966). However, upon closer examination the imbrication of the outer cycle elements in the distal shield are seen to be sinistral, not dextral as suggested by Gartner and Smith. Nonetheless, this sinistral imbrication is in agreement with Black (1964, pl. 50, fig. 2). The sutures in the distal shield of the Weches forms are inclined clockwise as in the transmission electronmicrograph and line drawing (1967, text-fig. 11) by Reinhardt and the electronmicrographs of Hay, Mohler and Wade, whereas Black and Gartner and Smith show counterclockwise inclinations.

Despite the above differences the Weches forms are assigned to this species because of their similar size, and their appearance in phase-contrast illumination and in cross-polarized light.

Hypotypes: Fort Bend County 6, 10180 (07.7; 73.8), W.U.M.C. 000216; Size: 12 microns. Smithville A SEM negative 5612; Size: 8.2 microns.

Occurrence: Reported from the early lower Eocene to near the lower Oligocene-middle Oligocene boundary in various parts of the world.

Genus ERICSONIA
Black, 1964

Description: Elliptical to circular placoliths with a well-defined elliptical central opening. The proximal shield consists of three concentric rings of crystals that are oriented in different directions.

Type Species: Ericsonia occidentalis Black.

ERICSONIA MUIRI
(Black)
Roth, 1970
Plate 3, figs. 21, 22
Plate 4, figs. 3, 7

Coccolithus muiri BLACK, 1964, p. 309, pl. 50, figs. 3, 4; HAQ, 1966, p. 29, pl. 1, fig. 3; pl. 4, figs. 4, 5.

Coccolithus eopelagicus (Bramlette and Riedel). GARTNER and SMITH, 1967, p. 3, pl. 3, figs. 1–5.

Ericsonia ovalis BLACK, 1964, p. 312, pl. 52, figs. 5, 6; STRADNER *in* STRADNER and EDWARDS, 1968, p. 17, pls. 8, 9; HAQ, 1968a, p. 21, pl. 1, figs. 4–9; pl. 2, figs. 1–4; pl. 4, figs. 1, 2; HAQ, 1971b, p. 70, pl. 10, fig. 10; HAQ, 1971c, p. 107, pl. 13, figs. 1, 2, 11; PERCH-NIELSEN, 1971a, p. 947, fig. 5; PERCH-NIELSEN, 1971b, p. 14, pl. 1, figs. 2, 4, 5; pl. 7, fig. 7; pl. 61, figs. 22,23; RAMSAY, 1971, p. 190, pl. 3, figs. 4, 5.

Ericsonia muiri (Black). ROTH, 1970, p. 841.

Remarks: Elliptical placoliths with the distal shield larger than the proximal shield. An elliptical central opening about one-third the width of the central area is present. Thirty-five elements are present in the outer cycle of the distal shield. The proximal disc consists of three cycles of crystal elements around the large central opening.

Hypotypes: Smithville F (20.2, 75.5), W.U.M.C. 000217; Size: 8.5 X 7 microns. Smithville A SEM negative 4876; Size: 7 microns long. SEM negative 5124; Size: 8.5 microns long.

Occurrence: Reported from the middle Eocene through the Oligocene in various parts of the world.

PLATE 3

The long axis of each specimen is parallel to
the polarizer unless otherwise specified.

Magnification 1800 X

Figures Page

1, 2 *Chiasmolithus grandis* (Bramlette and Riedel) Gartner 19
Distal view, 40 degrees clockwise from polarizer, from Smithville A (07.2; 70.1), W.U.M.C. 000210.

1. Phase-contrast
2. Between crossed-polarizers

3, 4 *Reticulofenestra umbilica* (Levin) Martini and Ritzkowski 29
Distal view, 45 degrees counterclockwise from polarizer, from Fort Bend County 6, 10180 (13.7; 75.5), W.U.M.C. 000219.

3. Phase-contrast
4. Between crossed-polarizers

5, 6 *Cruciplacolithus staurion* (Bramlette and Sullivan) Gartner 22
Distal view, from Hurricane Shoals 205 M (17.9; 76.8), W.U.M.C. 000214.

5. Phase-contrast
6. Between crossed-polarizers

7–10 *Cruciplacolithus delus* (Bramlette and Sullivan) Perch-Nielsen 21
Hypotype from Sabine River E (24.1; 79.4), W.U.M.C. 000213.

7. Distal view, phase-contrast
8 Distal view, between crossed-polarizers
9. Hypotype, proximal view, phase-contrast
10. Hypotype, proximal view, between crossed-polarizers

11, 12 *Reticulofenestra coenura* (Reinhardt) Roth 28
Distal view, 45 degrees clockwise from polarizers, from Smithville C (13.3; 74.7), W.U.M.C. 000218.

11. Phase-contrast
12. Between crossed-polarizers

13, 14 *Lophodolithus rotundus* Bukry and Percival 29
Distal view, from Hurricane Shoals J (10. 3; 70.5), W.U.M.C. 000220.

13. Phase-contrast
14. Between crossed-polarizers

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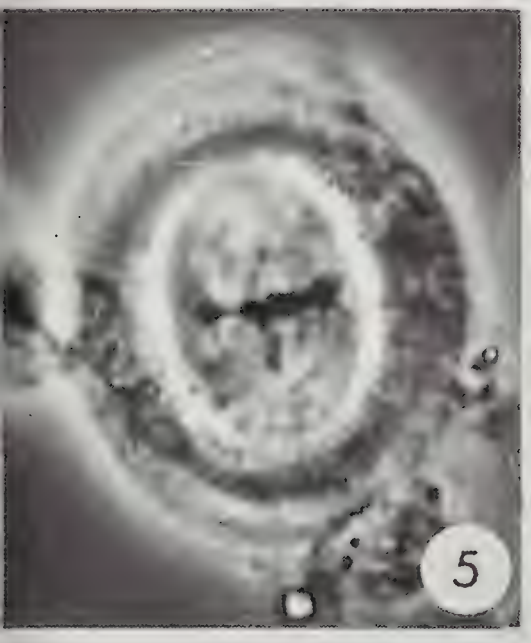
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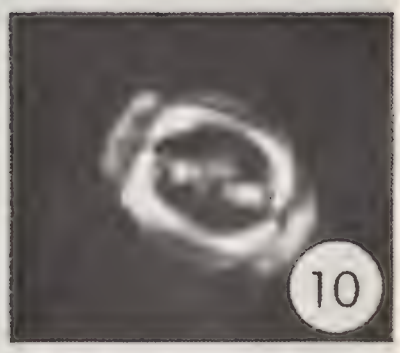
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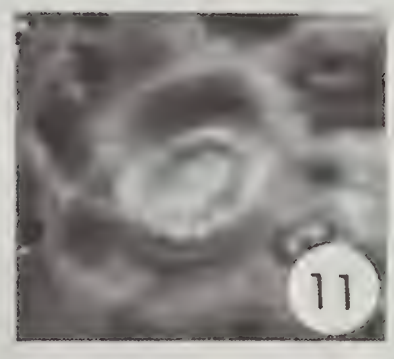
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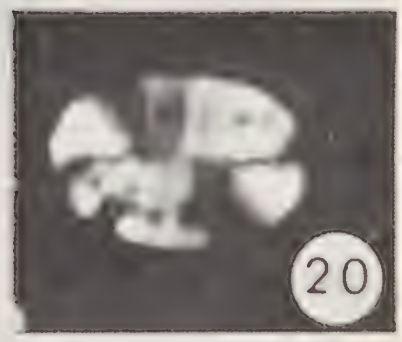
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PLATE 3

15, 16 *Pontosphaera multipora* (Kamptner) Roth 30
19, 20 Parallel to analyzer. Hypotype from Fort Bend County 6, 10180 (12.0; 75.4), W.U.M.C. 000221.

15. Distal view, phase-contrast
16. Distal view, between crossed-polarizers
19. Hypotype, proximal view, phase-contrast
20. Hypotype, proximal view, between crossed-polarizers

17, 18 *Cruciplacolithus tenuiforatus* Clocchiatti and Jerković 24
Distal view, from Hurricane Shoals M (21.95; 74.35), W.U.M.C. 000215.

17. Phase-contrast
18. Between crossed-polarizers

21, 22 *Ericsonia muiri* (Black) Roth 25
Proximal view, parallel to analyzer, from Smithville F (20.2; 75.5), W.U.M.C. 000217.

21. Phase-contrast
22. Between crossed-polarizers

23 *Pontosphaera pectinata* (Bramlette and Sullivan) n. comb 30
Distal view, parallel to analyzer, between crossed-polarizers, from Polk County 10, 6880 (29.3; 75.1), W.U.M.C. 000222.

24 *Pontosphaera plana* (Bramlette and Sullivan) Haq 31
Distal view?, between crossed-polarizers, from Sabine River E (06.9; 70.8), W.U.M.C. 000223.

Genus RETICULOFENESTRA
Hay, Mohler and Wade, 1966

Synonyms: Dictyococcites
Black, 1967;
Apertapetra
Hay, Mohler and Wade, 1966.

Description: Large sub-circular to elliptical placoliths bearing a large central opening. The central opening is spanned by a reticulate net of calcite elements.

Type Species: Reticulofenestra caucasica Hay, Mohler, and Wade.

RETICULOFENESTRA COENURA
(Reinhardt)
Roth, 1970
Plate 3, figs. 11, 12

Coccolithus coenurus REINHARDT, 1966, p. 516, pl. 1, fig. 7; text-fig. 6; REINHARDT, 1967, p. 207, pl. 2, figs. 2, 6; pl. 5, fig. 5; pl. 20, fig. 3; text-fig. 7; RADOMSKI, 1968, p. 561, pl. 45, figs. 3, 4.

Reticulofenestra coenura (Reinhardt). ROTH, 1970, p. 847; HAQ, 1971b, p. 72, pl. 1, figs. 10, 11; PERCH-NIELSEN, 1971a, p. 960, fig. 15; ROTH, BAUMANN, BERTOLINO, 1971, fig. 5.

Remarks: Subcircular placoliths with a concave proximal shield and a convex distal shield. Specimens range between 7–10 microns in length and 5–7 microns in width. The outer cycle of elements of the distal shield are so small as to not be resolvable at 1000 X with the oil immersion objective. The central area consists of a very narrow (about 0.5 micron wide) rim around a large central opening. The rim is much brighter than the outer cycle of elements of the distal shield. The central opening is approximately 4 microns long and 2 microns wide. In phase-contrast illumination no structures are seen to be present in the central opening. In cross-polarized light the central rim is very bright; narrow extinction zones which widen

towards the periphery of the distal shield originate here. The length and width of the distal shield and the central opening are rather variable.

Reticulofenestra coenura is smaller than *R. umbilica*. *R. pseudoumbilica* is similar to this species but is distinguished from it by having a shorter distance across the distal shield between the central opening and the periphery.

Hypotype: Smithville C (13.3; 74.7), W.U.M.C. 000218; Size: 8 X 7 microns.

Occurrence: Reported from the Eocene of Germany and the western Polish Carpathians, and the Oligocene in western Germany.

RETICULOFENESTRA UMBILICA
(Levin)
Martini and Ritzkowski, 1968
Plate 3, figs. 3, 4

Coccolithus sp. BOUCHÉ, 1962, p. 84, pl. 1, figs. 17, 21, 22.

Coccolithus pelycomorphus REINHARDT, 1967, p. 206, pl. 1, figs. 10, 11, 14; pl. 5, fig. 10; pl. 7, fig. 4.

Coccolithus umbilicus LEVIN, 1965, p. 265, pl. 41, fig. 2; MARTINI, 1967, p. 604; GARTNER and SMITH, 1967, p. 3, pl. 1, figs. 3, 4; pl. 2, figs. 1–3.

Apertapetra umbilica (Levin). LEVIN and JOERGER, 1967, p. 166, pl. 1, fig. 9; BRAMLETTE and WILCOXON, 1967, p. 101, pl. 5, figs. 1, 2.

Apertapetra samodurovi HAY, MOHLER and WADE, 1966, p. 387, pl. 6, figs. 1–5.

Reticulofenestra caucasica HAY, MOHLER and WADE, 1966, p. 386, pls. 3, 4; PERCH-NIELSEN, 1967, p. 26, pl. 1, figs. 9–11.

Reticulofenestra placomorpha STRADNER *in* STRADNER and EDWARDS, 1968, p. 22, pls. 19–21; pl. 22, fig. 1; pl. 23; pl. 24; pl. 25, figs. 1, 2; HAQ, 1968, p. 29, pl. 3, fig. 3; pl. 5, figs. 1–3.

Reticulofenestra umbilica (Levin). MARTINI and RITZKOWSKI, 1968, p. 245, pl. 1, figs. 11, 12; MARTINI, 1969, p. 137; ROTH, 1970, p. 852; GARTNER, 1971, figs. 1, 2, 4, 5; HAQ, 1971b, p. 77, pl. 7, figs. 5, 6; pl. 10, figs. 12, 13; MARTINI, 1971, p. 741, pl. 2, figs. 18, 19; PERCH-NIELSEN, 1971a, p. 960, fig. 15; PERCH-NIELSEN, 1971b, p. 30, pl. 21, fig. 7; pl. 23, figs. 1, 2; pl. 24, figs. 1–3; ROTH, BAUMANN, BERTOLINO, 1971, figs. 5–9.

?Reticulofenestra cf. *R. umbilica* (Levin) Martini and Ritzkowski. HAQ, 1971c, p. 112, pl. 13, figs. 13, 14.

Remarks: Large subcircular placolith with a large central opening spanned by a reticulate network of calcite elements. The proximal shield is smaller than the distal shield. The inner cycle of elements of the distal shield is brighter than the outer cycle in phase-contrast illumination and especially in cross-polarized light. The elements of the distal shield are barely resolvable at 1000 X with the oil immersion objective. Approximately 80 elements are present in the distal shield.

Hypotype: Fort Bend County 6, 10180 (13.7; 75.5), W.U.M.C. 000219; Size: 15 X 13 microns.

Occurrence: From the middle Eocene through the middle Oligocene in various parts of the world.

Family PONTOSPHAERACEAE
Lemmermann, 1908

Description: Coccolithophores bearing shallow lopadoliths which may or many not possess central spines.

Genus LOPHODOLITHUS
Deflandre, 1954

Description: Asymmetrical ellipsoidal rim that enlarges and thickens at one end and may or may not be crossed by a bridge.

Type Species: Lophodolithus mochlophorus Deflandre.

LOPHODOLITHUS ROTUNDUS
Bukry and Percival, 1971
Plate 3, figs. 13, 14

Lophodolithus rotundus BUKRY and PERCIVAL, 1971, p. 134, pl. 5, figs. 6, 7.

Remarks: Large asymmetrical ellipsoidal lophodolith with a nearly circular central opening located near the end of the plate where the rim, or outer cycle of elements, is narrowest. The diameter of the central opening is equal to one-third to one-half the

length of the long axis of the ellipse. The rim gradually widens from its narrowest point until it is two-and one-half to three times wider at the opposite end of the long axis of the ellipse. The rim consists of many fine radially disposed elements. The elements become longer and wider as the widest end of the rim is approached.

Hypotype: Hurricane Shoals J (10.3; 70.5), W.U.M.C. 000220; Size: 16 X 12 microns.

Occurrence: Reported from the middle Eocene of a South Pacific deep-sea core.

Genus PONTOSPHAERA
Lohmann, 1902

Description: Simple shallow lopadoliths (lopodolith) with a continuous elliptical wall composed of many thin imbricate laths. The height of the wall does not exceed the longest diameter of the base plate.

Type Species: Pontosphaera syracusana Lohmann.

PONTOSPHAERA MULTIPORA
(Kamptner)
Roth, 1970
Plate 3, figs. 15, 16, 19, 20
Plate 4, figs. 8, 9

Discolithus multiporus KAMPTNER, 1948, p. 5, pl. 1, fig. 9; STRADNER, 1964, p. 134, text-figs. 4–8; CLOCCHIATTI, 1971, p. 48, pl. 12, figs. 1–8, text-fig. 6.

Discolithus confossus (Hay, Mohler and Wade). CLOCCHIATTI, 1971, p. 46, pl. 11, figs. 1, 2, 4.

Discolithus crassus DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 30, pl. 15, figs. 12, 13; text-fig. 49.

Discolithus distinctus BRAMLETTE and SULLIVAN, 1961, p. 141, pl. 2, figs. 8, 9; SULLIVAN, 1964, p. 182, pl. 4, fig. 4; SULLIVAN, 1965, p. 33, pl. 4, figs. 1–6; REINHARDT, 1967, p. 212, pl. 3, fig. 4.

Discolithus cf. *distinctus* COHEN, 1965a, p. 15, pl. 3, figs. r-–t.

Discolithus distinctoides REINHARDT, 1967, p. 212, pl. 3, figs. 2, 3, 6.

Discolithina multipora (Kamptner). MARTINI, 1965, p. 400; HAQ, 1968, p. 36, pl. 6, figs. 4–9; STRADNER and EDWARDS, 1968, p. 35, pls. 32–35; text-fig. 7; STRADNER, 1969, p. 665, pl. 2, figs. 1, 2; pls. 3, 4; ACHUTHAN and STRADNER, 1969, p. 6; PERCH-NIELSEN, 1971b, p. 34, pl. 26, figs. 1–5.

Discolithina confossa HAY, MOHLER and WADE, 1966, p. 392, pl. 9, figs. 1–9; LOCKER, 1968, pl. 1, fig. 18.

Discolithina distincta (Bramlette and Sullivan). LEVIN and JOERGER, 1967, p. 166, pl. 1, figs. 14, 15; MARTINI, 1969b, p. 134, pl. 1, figs. 7, 8; MARTINI and RITZKOWSKI, 1968, p. 245, pl. 1, figs. 7, 8.

Discolithina sp. aff. *D. distincta* (Bramlette and Sullivan). GARTNER and SMITH, 1967, p. 5, pl. 6, figs. 4–6.

Discolithina sp. BUKRY and BRAMLETTE, 1969, pl. 6, fig. D.

Pontosphaera vadosa HAY, MOHLER and WADE, 1966, p. 391, pl. 8, fig. 4; *non* pl. 8, figs. 1–3; PERCH-NIELSEN, 1967, p. 26, pl. 2, figs. 6–9; HODSON and WEST, 1970, p. 175, pl. 4, fig. 2.

Pontosphaera multipora (Kamptner). ROTH, 1970, p. 860; HAQ, 1971a, p. 21; HAQ, 1971b, pl. 4, figs. 4–6, 8, 9; pl. 7, figs. 3, 4; pl. 14, figs. 4, 5.

Remarks: Elliptical discolith with 40–45 perforations arranged in three concentric ellipses in the base plate. An imperforate peripheral rim is attached to the edge of the base plate. The peripheral rim is two to three times higher than the thickness of the base plate. The base plate is concave proximally and convex distally. Under phase-contrast illumination the proximal surface shows the presence of rectangular laths oriented with their long axis perpendicular to the long axis of the ellipse. The distal view shows only the perforations. A longitudinal suture parallels the long axis of the ellipse and is visible from both sides of the base plate.

Hypotypes: Fort Bend County 6, 10180 (12.0; 75.4), W.U.M.C. 000221; Size: 12 X 8 microns. Fort Bend County 6,9490, SEM negative 5915; Size: 11 X 7 microns. Hurricane Shoals J, SEM negative 6437; Size: 11 X 7 microns.

Occurrence: Reported from the middle and upper Eocene to the Miocene in various parts of the world.

PONTOSPHAERA PECTINATA
(Bramlette and Sullivan)
n. comb
Plate 3, fig. 23
Plate 4, fig. 4

Discolithus pectinatus BRAMLETTE and SULLIVAN, 1961, p. 142, pl. 3, figs. 4, 5; SULLIVAN, 1964, p. 183, pl. 4, fig. 8; SULLIVAN, 1965, p. 34.

Discolithina pectinata (Bramlette and Sullivan). LEVIN, 1965, p. 266, pl. 41, fig. 8; LEVIN and JOERGER, 1967, p. 167, pl. 2, fig. 4; PERCH-NIELSEN, 1967, p. 25, pl. 2, figs. 10–12; ACHUTHAN and STRADNER, 1969, p. 6, pl. 2, fig. 6; GARTNER, 1971, fig. 5; PERCH-NIELSEN, 1971b, p. 35, pl. 26, fig. 6.

Remarks: Discolith with a moderately wide rim containing 20–25 vertical ribs. The discolith is concave proximally and convex distally. The base plate has two subcircular perforations. The crossbar which separates the perforations bears a longitudinal slit. In cross-polarized light the interference isogyres look very much like a biaxial interference figure. The apices of the isogyres are located at the sites of the perforations.

The SEM micrograph shows a specimen that has some overgrowths along the rim. The overgrowths have made the vertical ribs appear shorter than those in the specimens figured by Bramlette and Sullivan (1961, pl. 3, figs. 4, 5). This species is distinguished from *P. pulchra* by having circular rather than semicircular openings in the base plate, by a longitudinal line which bisects the base plate, and by having more of the base plate visible. *Discolithina panarium* is larger and has perforations along the rim, whereas *P. pectinata* has no perforations along the rim.

Hypotypes: Polk County 10, 6880 (29.3; 75.1), W.U.M.C. 000222; Size: 9 X 7.5 microns. Sabine River E, SEM negative 6395; Size: 10.5 X 8 microns.

Occurrence: Reported from the upper Paleocene through the lower Oligocene.

PONTOSPHAERA PLANA

(Bramlette and Sullivan)
Haq, 1971
Plate 3, fig. 24
Plate 5, figs. 3, 4

Discolithus planus BRAMLETTE and SULLIVAN, 1961, p. 143, pl. 3, fig. 7; SULLIVAN, 1964, p. 183, pl. 4, fig. 6; SULLIVAN, 1965, p. 34; *non* COHEN, 1965a, p. 14, pl. 2, figs. p–s; REINHARDT, 1967, p. 214, pl. 3, figs. 12, 16; text-fig. 16.

Discolithina plana (Bramlette and Sullivan). LEVIN, 1965, p. 266, pl. 41, fig. 9; LEVIN and JOERGER, 1967, p. 167, pl. 2, fig. 3; HAQ, 1967, p. 59, pl. 6, figs. 1–3; BUKRY and KENNEDY, 1969, p. 42, fig. 3, no. 10; BILGÜTAY *et al.*, 1969, pl. 4, figs. 8, 9; PERCH-NIELSEN, 1971b, p. 35, pl. 29, fig. 4.

Pontosphaera plana (Bramlette and Sullivan). HAQ, 1971a, p. 22, pl. 10, fig. 1; pl. 12, fig. 6; HAQ, 1971b, p. 82; HAQ, 1971c, p. 113, pl. 11, figs. ?5-8; pl. 21, fig. 1; RAMSAY, 1971, p. 206.

Remarks: Discoliths with thick elongate elliptical base plates. The surface of the plate is smooth, bearing two slightly sigmoid slits near the ends of the long axis of the ellipse. The plate is concave proximally, convex distally and is not bordered by a rim. In cross-polarized light a biaxial interference figure is produced when the long axis of the ellipse is rotated a few degrees counterclockwise from the direction of the polarizer. When the long axis parallels the polarizer a black band cuts diagonally across the plate.

The assignment of this species to the genus *Pontosphaera* seems questionable. *Pontosphaera* contains forms with a continuous wall, a feature not present in *P. plana.* In well samples 6880 and 8365 specimens of *P. plana* were observed with a small perforation at the inner end of the sigmoid slits. However, *P. plana* does not conveniently fit into the genus *Transversopontis* because it lacks two large openings. It appears that *P. plana* should have been retained in *Discolithina.*

Hypotype: Sabine River E (06.9; 70.8), W.U.M.C. 000223; Size: 10 X 6 microns.

Occurrence: Reported from the Paleocene through the middle Oligocene in various parts of the world.

PONTOSPHAERA VERSA

(Bramlette and Sullivan)
n. comb.
Plate 5, figs. 1, 2
Plate 4, fig. 10

Discolithus versus BRAMLETTE and SULLIVAN, 1961, p. 144, pl. 3, fig. 16; SULLIVAN, 1964, p. 183, pl. 4, fig. 11; SULLIVAN, 1965, p. 35, pl. 5, figs. 8, 9.

Discolithina sp. cf. *D. versa* (Bramlette and Sullivan). LEVIN and JOERGER, 1967, p. 168, pl. 2, fig. 11.

Remarks: Elliptical discoliths with a low, moderately wide rim enclosing the base plate. Under phase-contrast illumination the long axis of the ellipse is outlined by a narrow line, the ends of which thicken and appear as sigmoid slits. The discolith is concave proximally and convex distally. In cross-polarized light a black band cuts diagonally across the plate. SEM micrographs show that the rim is only a little thicker than the base plate. As seen from the distal side the rim and base plate appear to be constructed of rectangular crystal laths. The axes of the laths are annularly disposed. The annular arrangement of laths appears quite similar to that shown for *Pontosphaera multipora* by Stradner *in* Stradner and Edwards (1968, p. 36, fig. 7a).

The SEM and light micrographs are of the same specimen. A close systematic relationship with *Pontosphaera multipora* is suggested on the basis of the similarity of arrangement and form of the rectangular laths seen in distal view.

Hypotype: Sabine River E, SEM negative 6338; Size: 13 X 11 microns.

PLATE 4

Magnification 4500 X

Figures — Page

1 *Cruciplacolithus tenuiforatus* Clocchiatti and Jerković 24
Proximal view, from Smithville D_2, SEM negative 5818.

2 *Cyclococcolithina formosa* (Kamptner) Wilcoxon 24
Distal view, from Smithville A, SEM negative 5612

3, 7 *Ericsonia muiri* (Black) Roth 25
From Smithville A.

3. Proximal view, SEM negative 4876
7. Distal view, SEM negative 5124

4 *Pontosphaera pectinata* (Bramlette and Sullivan) n. comb. 30
Distal view, from Sabine River E, SEM negative 6395.

5, 6 *Koczyia wechesensis* (Bukry and Percival) n. comb. 34
From Smithville A.

5. Proximal view, SEM negative 4877
6. Distal view, SEM negative 2

8, 9 *Pontosphaera multipora* (Kamptner) Roth 30
Distal view.

8. From Fort Bend County 6, 9490, Sem negative 5915
9. From Hurricane Shoals J, SEM negative 6437

10 *Pontosphaera versa* (Bramlette and Sullivan) n. comb. 31
Distal view, from Sabine River E, SEM negative 6338.

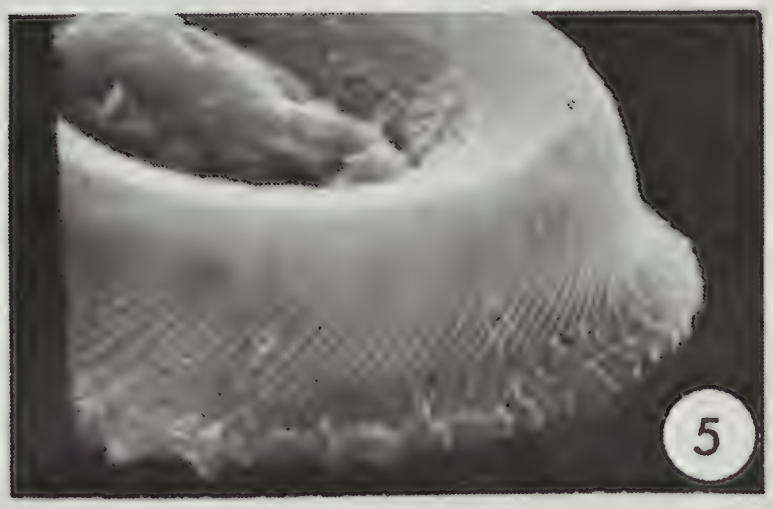

PLATE 4

Occurrence: Reported from the upper Paleocene through the lower and middle Oligocene in North America.

Genus KOCZYIA
Boudreaux and Hay, 1969

Description: Lopadoliths (lopodoliths) having a distal margin which flares outward abruptly.

Type Species: Koczyia lepida Boudreaux and Hay.

KOCZYIA WECHESENSIS
(Bukry and Percival)
n. comb.
Plate 4, figs. 5, 6
Plate 5, figs. 5, 6

?Syracosphaera wechesensis BUKRY and PERCIVAL, 1971 p. 142, pl. 7, figs. 7–10.

Discolithina amphitheatralis LEVIN and SHERWOOD, 1971, p. 731. text-fig. 1.

Koczyia excelsa PERCH-NIELSEN, 1971b, p. 37, pl. 28, figs. 1–5; pl. 60, fig. 16.

Remarks: Crown-shaped discoliths with a large central opening and a broad rim. The rim is ornamented by 19–23 elliptical depressions, each separated by a steeply inclined buttress. The outer rim is composed of approximately 150 inclined crystal laths which are covered on the proximal side by a circle of rectangular crystal elements. The elements of the rim terminate distally in an irregular flange which overhangs the periphery of the rim. In cross-polarized light a biaxial interference pattern is observed. The discolith is only slightly concave proximally and convex distally.

The photomicrographs are of topotype material for *?Syracosphaera wechesensis,* provided by David Bukry. Study of this material produced only specimens assignable to *Discolithina amphitheatralis.* The species name *wechesensis* has priority because it appeared in print three months before *D. amphitheatralis.* Transfer is made to the genus *Koczyia* because of the continuous rim of thin imbricate laths which terminate distally in a flange overhanging the rim.

Hypotype: Roberts School, San Augustine County, Texas 1 (28.9; 76.7), W.U.M.C. 000224; Size: 10 X 8 microns. Smithville A , SEM negatives 2 and 4877.

Occurrence: Reported from the lower Eocene in Denmark and the middle Eocene in Texas, Alabama and the Caucasus Mountains of the U.S.S.R.

Genus TRANSVERSOPONTIS
Hay, Mohler and Wade, 1966

Description: Shallow elliptical lopodoliths with two large openings in the ends of the ellipse separated by a central bridge.

Type Species: Transversopontis obliquipons (Deflandre) Hay, Mohler, and Wade.

TRANSVERSOPONTIS OCELLATUS
(Bramlette and Sullivan)
n. comb.
Plate 5, figs. 7, 8
Plate 6, figs. 3, 4

Discolithus ocellatus BRAMLETTE and SULLIVAN, 1961, p. 142, pl. 3, fig. 2; HAY and TOWE, 1962, p. 501, pl. 8; SULLIVAN, 1964, p. 183, pl. 4, figs. 1, 2; SULLIVAN, 1965, p. 34; REINHARDT, 1967, p. 213, pl. 3, figs. 9, 13, 17; text-fig. 15.

Discolithina ocellata (Bramlette and Sullivan). PERCH-NIELSEN, 1971b, pl. 29, fig. 6.

Crepidolithus ocellatus (Bramlette and Sullivan). RAMSAY, 1971, p. 206.

Pontosphaera ocellata (Bramlette and Sullivan). RAMSAY, 1971, p. 206.

Remarks: Elliptical discoliths with moderately thick plates and without encircling rims. SEM micrographs show the discolith to be made up of a proximal plate and a slightly larger distal plate. These two plates are welded to each other. The proximal surface is smooth and concave. The distal surface bears long thin laths which are annularly arranged. The plate is penetrated by two perforations located along the long axis of the ellipse. The perforations are separated by a moderately wide crossbar, which is interrupted near its center by a longitudinal slit. In cross-polarized light a wide extinction band cuts diagonally across the plate when the long axis is oriented parallel to the direction of the analyzer of polarizer.

It is assumed that the electron micrograph figured by Hay and Towe (1962) is a view of the proximal surface of a

specimen that is better preserved than those found within the Weches Formation. Specimens did not show the high birefringence reported by Bramlette and Sullivan.

Hypotypes: Smithville A (19.4; 74.9), W.U.M.C. 000225; Size: 10 X 7.5 microns. Smithville D_1, SEM negative 5817; Size: 10 X 8 microns. Smithville A, SEM negative 5685; Size: 10 X 7.5 microns.

Occurrence: Reported from the Paleocene and Eocene in North America and the Eocene in Germany and France.

TRANSVERSOPONTIS PULCHRA
(Deflandre)
Haq, 1971
Plate 5, figs. 11, 12
Plate 6, figs. 1, 2

Discolithus pulcher DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 142, pl. 12, figs. 17, 18; BRAMLETTE and SULLIVAN, 1961, p. 143, pl. 3, fig. 8; MANIVIT, 1961, p. 344, pl. 1, fig. 8; NARASIMHAN, 1961, p. 149, pl. 7, fig. 12; BOUCHÉ, 1962, p. 82, pl. 7, figs. 7, 8; text-fig. 2; SULLIVAN, 1964, p. 183, pl. 4, fig. 7; SULLIVAN, 1965, p. 34, pl. 5, REINHARDT, 1967, p. 214, pl. 3, figs. 10, 14; text-fig. 17.

Discolithina pulchra (Deflandre). LEVIN, 1965, *non* p. 266, pl. 41, fig. 6; BUKRY and KENNEDY, 1969, p. 42, fig. 3, no. 11; ACHUTHAN and STRADNER, 1969, p. 6, pl. 2, fig. 4.

Transversopontis pulcher (Deflandre). HAY, MOHLER and WADE, 1966, p. 391, (transfer invalid); PERCH-NIELSEN, 1967, p. 27, pl. 3, figs. 9–11; PERCH-NIELSEN, 1971a, p. 956, fig. 13; PERCH-NIELSEN, 1971b, p. 39, pl. 28, fig. 6; pl. 31, figs. 2, 3; pl. 32, figs. 5, 6; HAQ, 1971b, p. 85, pl. 5, figs. 10, 11; pl. 17, fig. 3.

Transversopontis pulcher (Deflandre). HAQ, 1971, p. 23.

Pontosphaera pulcher (Deflandre). RAMSAY, 1971, *non* p. 206, pl. 4, fig. 1 (transfer invalid).

Remarks: Shallow elliptical lopodoliths which are only slightly concave proximally and slightly convex distally. Proximal view of this species reveals a thin base plate surmounted by a thick layer of 150-200 imbricate laths. The rim formed by the laths flares distally and is only a little thicker than the central area. The central area of the lopodolith is perforated by two large semicircular openings separated by a transverse bar. The crossbar is inclined only slightly to the minor axis of the ellipse and is interrupted by a slit at its half-length. When viewed under phase-contrast the specimens show about 20 slots or ridges perpendicular to the periphery of the lopodolith. SEM micrographs of corroded specimens reveal the presence of tunnels beneath the base plate. These tunnels are normally covered by the imbricate rim elements. It is believed that these tunnels produce the slots or ribs observed in the light microscope.

The crossbar in this species more closely parallels the short axis of the ellipse than the crossbar in *T. pulcheroides.*

Hypotypes: Smithville D_2 (21.7; 75.4), W.U.M.C. 000226; Size: 9 X 7 microns. Smithville A, SEM negative 5658; Size: 7 X 5 microns. SEM negative 5823; Size: 8 X 6 microns.

Occurrence: Reported from the Paleocene through the Eocene in various parts of the world.

TRANSVERSOPONTIS PULCHEROIDES
(Sullivan)
Perch-Nielsen, 1971
Plate 5, figs. 15, 16

Discolithus pulcheroides SULLIVAN, 1964, p. 183, pl. 4, fig. 7; SULLIVAN, 1965, p. 34; REINHARDT, 1967, p. 214, pl. 3, fig. 18; pl. 4, fig. 5; text-fig. 18.

Discolithus aff. *D. pulcher* BRAMLETTE and SULLIVAN, 1961, p. 143, pl. 3, figs. 9, 10.

Discolithina pulchra (Deflandre). LEVIN, 1965, p. 266, pl. 41, fig. 6.

Discolithina pulcheroides (Sullivan). LEVIN and JOERGER, 1967, p. 167, pl. 2, fig. 8; STRADNER and EDWARDS, 1968, p. 38, pl. 38, figs. 6–10; HAQ, 1968, p. 38, pl. 7, figs. 1–3; MARTINI and RITZKOWSKI, 1968, p. 245, pl. 1, fig. 4; RADOMSKI, 1968, p. 570; MARTINI, 1969b, p. 135, pl. 1, figs. 9–10; ACHUTHAN and STRADNER, 1969, p. 6, pl. 2, fig. 5.

Discolithina sp. cf. *D. pulcheroides* (Sullivan). GARTNER and SMITH, 1967, p. 4, pl. 6, figs. 1–3.

PLATE 5

The long axis of each specimen is parallel to
the polarizer unless otherwise specified.

Magnification 1800 X

Figures Page

1, 2 *Pontosphaera versa* (Bramlette and Sullivan) n. comb. 31
Distal view, from Sabine River E.

1. Phase-contrast
2. Between crossed-polarizers

3, 4 *Pontosphaera plana* (Bramlette and Sullivan) Haq 31
Distal view, from Sabine River E, (06.9; 70.8), W. U. M.C. 000223.

3. 23 degrees counterclockwise from polarizer, between crossed-polarizers
4. Parallel to polarizer, between crossed-polarizers

5, 6 *Koczyia wechesensis* (Bukry and Percival) n. comb. 34
Topotype, distal view, from Roberts School, San Augustine County 1 (28.9; 76.7), W.U.M.C. 000224.

5. Phase-contrast
6. Between crossed-polarizers

7, 8 *Transversopontis ocellatus* (Bramlette and Sullivan) n. comb 34
Distal view, from Smithville A (19.4; 74.9), W.U.M.C. 000225.

7. Phase-contrast
8. Between crossed-polarizers

9, 10 *Helicopontosphaera seminulum* (Bramlette and Sullivan) Roth 39
Proximal view, from Sabine River E, Photomicrograph negatives 16–5, 16–6.

9. Phase-contrast
10. Between crossed-polarizers

11, 12 *Transversopontis pulchra* (Deflandre) Haq 35
Parallel to analyzer, from Smithville D_2 (21.7; 75.4), W.U.M.C. 000226.

11. Phase-contrast
12. Between crossed-polarizers

13, 14 *Helicopontosphaera lophota* (Bramlette and Sullivan) Perch-Nielsen 40
Distal view?, from Sabine River E, Photomicrograph negatives 18–9, 18–10.

13. Phase-contrast
14. Between crossed-polarizers

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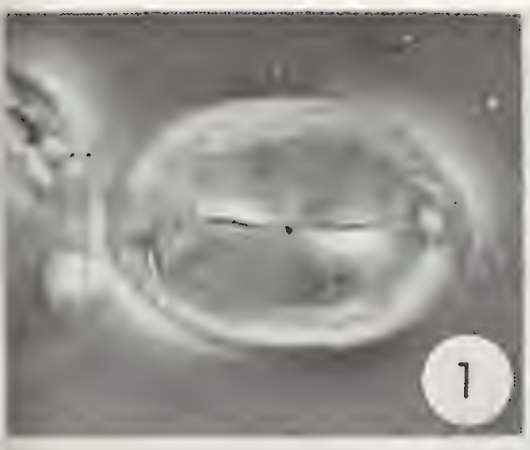
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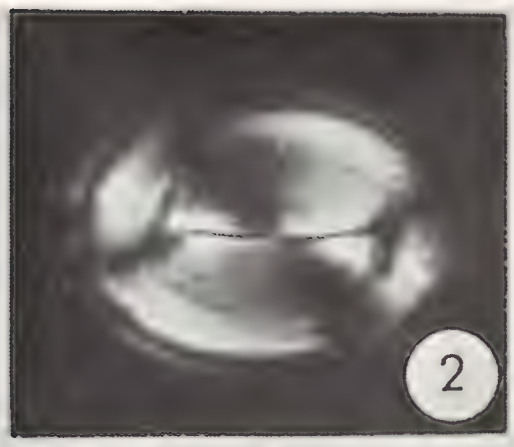
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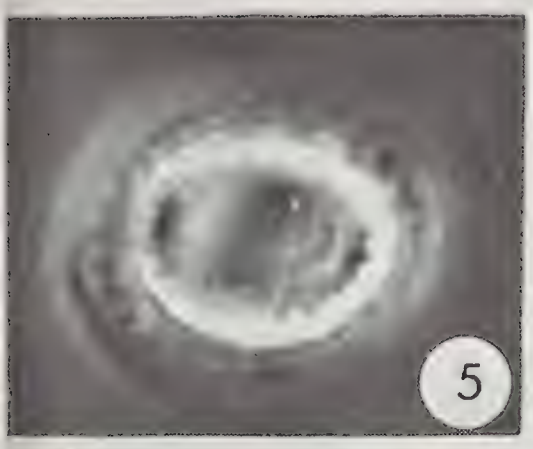
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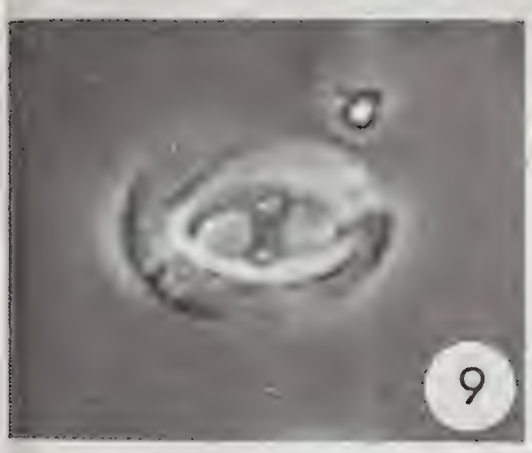
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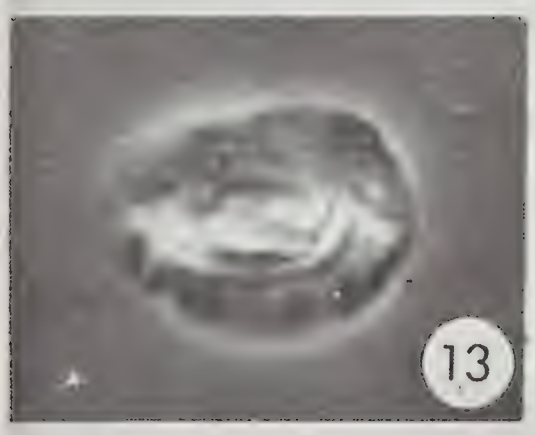
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PLATE 5

15, 16 *Transversopontis pulcheroides* (Sullivan) Perch-Nielsen 35
Distal view, parallel to analyzer, from Smithville A (13.2; 75.8), W.U.M.C. 000227.

15. Phase-contrast
16. Between crossed-polarizers

17, 18 *Transversopontis pulchriporus* (Reinhardt) n. comb. 39
Distal view, from Smithville A (15.5; 74.0), W.U.M.C. 000228.

17. Phase-contrast, 20 degrees counterclockwise from polarizer
18. Between crossed-polarizers, parallel to analyzer

19–22 *Blackites tenuis* (Bramlette and Sullivan) n. comb. 42
From Hurricane Shoals M (20.3; 79.8), W.U.M.C. 000232.

19. Phase-contrast
20. Between crossed-polarizers
21. Phase-contrast, parallel to analyzer
22. Between crossed-polarizers, parallel to analyzer

23 *Blackites scabrosus* (Deflandre) Roth 41
Between crossed-polarizers, from Hurricane Shoals J (28.3; 73.7), W.U.M.C. 000237.

24 *Rhabdolithes rudis* (Bramlette and Sullivan) n. comb. 45
Between crossed-polarizers, from Fort Bend County 6, 9490 (08.2; 77.1), W.U.M.C. 000233.

25, 26 *Blackites creber* (Deflandre) n. comb. 41
Distal view, from Hurricane Shoals M. (26.2; 74.2), W.U.M.C. 000230.

25. Phase-contrast
26. Between crossed-polarizers

Transversopontis obliquipons (Deflandre).
PERCH-NIELSEN, 1967, p. 27, pl. 3, figs. 6–8; HODSON and WEST, 1971, p. 174, pl. 2, fig. 4; *non* pl. 1, fig. 4; HAQ, 1971b, p. 84, pl. 7, figs. 5, 6; pl. 8, figs. 1–9; pl. 17, figs. 2, 3.

Transversopontis pulcheroides (Sullivan).
PERCH-NIELSEN, 1971a, p. 360, fig. 13 (transfer invalid).

Transversopontis pulcheroides (Sullivan).
PERCH-NIELSEN, 1971b, p. 40, pl. 33, figs. 3, 7.

Remarks: Elliptical discoliths with two large semicircular perforations separated by a moderately wide obliquely disposed crossbar. The imperforate crossbar is interrupted at its half-length by a slit parallel to the long axis of the ellipse. On the distal side the periphery of the discolith is made up of a band of rectangular crystal laths annularly arranged. Inside this band of crystal laths a ring of 11–15 depressions are found. No true wall surrounds the discolith, and no true perforations are observed. The discolith is concave proximally and convex distally.

The transverse central bar is more oblique than the crossbar in *T. pulchra.* In the light microscope *T. pulchra* appears to bear slots whereas *T. pulcheroides* bears circular depressions. The distance from the depressions to the periphery in *T. pulcheroides* is greater than the distance in *T. pulchriporus.*

Hypotype: Smithville A (13.2; 75.8), W.U.M.C. 000227; Size: 7 X 5 microns.

Occurrence: Reported from the Paleocene through the lower and middle Oligocene in various parts of the world.

TRANSVERSOPONTIS PULCHRIPORUS
(Reinhardt)
n. comb.
Plate 5, figs. 17, 18
Plate 6, fig. 6

Discolithus pulchriporus REINHARDT, 1967, p. 214, pl. 3, figs. 21–23; pl. 7, fig. 3.

Remarks: Elliptical discoliths gently convex distally and concave proximally. Two large semicircular perforations are located along the long axis of the ellipse. These perforations are separated by a moderately wide obliquely disposed crossbar which thins toward the center and is interrupted at its half-length by a slit. In distal view the plate is seen to be bordered by a low moderately wide rim. Between the peripheral rim and the semicircular perforations a single row of 14–18 elliptical depressions surround the discolith. At each end of the crossbar inside the row of depressions, one and sometimes two additional depressions are present. In phase-contrast and in cross-polarized light all depressions appear as perforations. The depressions are most easily seen in cross-polarized light, especially those at the end of the crossbar.

When observed in the light microscope this species is distinguished from *T. pulchra* by the presence of an oblique rather than straight bridge and by round, pore-like perforations rather than ridges or slots near the periphery of the discolith. *T. pulcheroides* does not have perforations at the ends of the crossbar as *T. pulchriporus* does. The depressions are located closer to the periphery of the discolith in *T. pulchriporus* than in *T. pulcheroides.*

Hypotypes: Smithville A (15.5; 74.0), W.U.M.C. 000228; Size: 7 X 4.5 microns. Smithville A, SEM negative 5621; Size: 6 microns long.

Occurrence: Reported from the Eocene in Germany.

Genus HELICOPONTOSPHAERA
Hay and Mohler, 1967

Description: Complex shallow lopodoliths with a spiral wall.

Type Species: Helicopontosphaera kamptneri Hay and Mohler.

HELICOPONTOSPHAERA SEMINULUM
(Bramlette and Sullivan)
Roth, 1970
Plate 5, figs. 9, 10
Plate 6, fig. 8

Helicosphaera seminulum seminulum BRAMLETTE and SULLIVAN, 1961, p. 144, pl. 4, figs. 1, 2; HAY and TOWE, 1962, p. 512, pl. 1, figs. 1–3; 5; SULLIVAN, 1964, p. 184, pl. 5, fig. 1; SULLIVAN, 1965, p. 35; PERCH-NIELSEN, 1967, pl. 3, figs. 4, 5; CLOCCHIATTI, 1971, p. 40, pl. 17; figs. 2–4; GARTNER, 1971, figs. 1, 4, 5.

Helicosphaera aff. *H. seminulum* Bramlette and Sullivan. BRAMLETTE and WILCOXON, 1967, p. 106, pl. 5, figs. 11, 12.

Helicosphaera seminulum Bramlette and Sullivan. ACHUTHAN and STRADNER, 1969, p. 6, pl. 2, figs. 7, 8.

Helicopontosphaera seminulum seminulum (Bramlette and Sullivan). BUKRY and KENNEDY, 1969, p. 42 (transfer invalid).

Helicopontosphaera seminulum (Bramlette and Sullivan). ROTH, 1970, p. 863; HAQ, 1971b, p. 87; PERCH-NIELSEN, 1971a, p. 956, fig. 14; PERCH-NIELSEN, 1971b, p. 44, pl. 34, fig. 4; pl. 35, figs. 1, 2, 5, 6; pl. 36, figs. 4, 7, 8; pl. 37, fig. 6. RAMSAY, 1971, p. 206, pl. 3, fig. 7.

Remarks: Elliptical helicoid coccolith with two curved plates. When viewed from the proximal side a smaller proximal plate is observed. The distal plate and the proximal plate are one and the same for the full length of one side of the plate at which point two separate plates are formed. The distal plate is now distinct from the proximal plate and continues to spiral outward along the remaining side of the proximal plate. As the distal plate spirals around the coccolith it gradually widens until at the end opposite the initial separation of the two plates it is wider than the previous cycle, and wider than the other end of the placolith. The termination of the spiraling distal plate is usually more abrupt than that observed in

the electronmicrographs. When viewed with phase-contrast the portion of the coccolith where the two plates fuse is quite distinct as is the remainder of the proximal shield. A distinctive crossbar, aligned with the short axis of the elliptical plate, divides the central opening into two sub-rectangular openings. The crossbar is located in the proximal shield.

The phase-contrast and SEM micrographs are of the same specimen. The blurred top side of Figure 9, Plate 5, represents that portion of the coccolith where the proximal and distal shield are fused. The sharper bottom half represents that portion where the plates have become separated.

Hypotype: Sabine River E, Photomicrograph negatives 16–5, 16–6. SEM negative 6471; Size: 11 X 8 microns.

Occurrence: Reported from the Paleocene through the middle Oligocene.

HELICOPONTOSPHAERA LOPHOTA
(Bramlette and Sullivan)
Haq, 1971
Plate 5, figs. 13, 14

Helicosphaera seminulum lophota BRAMLETTE and SULLIVAN, 1961, p. 144, pl. 4, figs. 3, 4; SULLIVAN, 1964, p. 184, pl. 5, fig. 1; SULLIVAN, 1965, p. 35, pl. 6, fig. 5; PERCH-NIELSEN, 1967, p. 25, pl. 3, figs. 1–3; GARTNER, 1971, figs. 1, 4, 5.

Helicosphaera seminulum Bramlette and Sullivan. GARTNER and SMITH, 1967, p. 5, pl. 7, figs. 1–4; STRADNER and EDWARDS, 1968, p. 38, pls. 39, 40.

Helicopontosphaera seminulum lophota (Bramlette and Sullivan). BUKRY and KENNEDY, 1969, p. 42, fig. 4, nos. 2, 3 (transfer invalid).

Helicopontosphaera lophota (Bramlette and Sullivan). PERCH-NIELSEN, 1971a, p. 956, fig. 14 (transfer invalid).

Helicopontosphaera lophota (Bramlette and Sullivan). HAQ, 1971b, p. 87, pl. 3, fig. 12; HAQ, 1971c, p. 116, pl. 10, figs. 8, 9. PERCH-NIELSEN, 1971b, p. 43, pl. 34, figs. 1, 2; pl. 36, figs. 1, 2.

Helicopontosphaera seminulum lophota (Bramlette and Sullivan). GARTNER, 1971, p. 116.

Remarks: Elliptical to subcircular placoliths with a wide single cycle of elements in the distal shield when viewed from the distal side. Two small subcircular openings are present along the long axis of the ellipse. The two perforations are separated by a narrow bridge which is inclined at an angle of a few degrees to the long axis of the ellipse. One end of the plate is wider than the other. In cross-polarized light a black sigmoid isogyre runs the length of the plate paralleling the long axis.

This species is wider than *H. seminulum* throughout its length and at the enlarged end. The openings in the central area are much smaller than those in *H. seminulum.*

Hypotype: Sabine River E, Photomicrograph negatives 18–9, 18–10; Size: 11.5 X 10 microns.

Occurrence: Reported from the upper Paleocene into the upper Eocene in North America and Europe.

Family RHABDOSPHAERACEAE
Lemmermann, 1908

Description: Coccolithophores bearing rhabdoliths that may be club or nail-shaped.

Genus BLACKITES
(Hay and Towe)
Stradner, 1968

Description: Rhabdoliths with distally tapering shafts attached to the distal side of a circular basal plate composed of at least three cycles of radially or tangentially arranged crystal elements.

Type species: Blackites rectus (Deflandre) Stradner.

BLACKITES AMPLUS
Roth and Hay, 1967
Plate 6, figs. 9, 10
Plate 7, figs. 3, 4

Blackites amplus ROTH and HAY, 1967, p. 445, pl. 7, fig. 10; ROTH, 1970, p. 857, pl. 7, fig. 6; PERCH-NIELSEN, 1971a, p. 963, fig. 16.

Blackites spinosus (Deflandre and Fert) Hay and Towe. BLACK, 1965, p. 134, fig. 17; HODSON and WEST, 1970, p. 186, pl. 2, fig. 5; text-fig. 3.

Remarks: Circular plates approximately 6–7 microns across. With phase-contrast the plates are seen to bear a central circular perforation nearly 2 microns in diameter. A

smooth ring surrounds the central perforation and is in turn surrounded by a narrow (0.2 micron) depression and a cycle of trapezohedral elements. Between 26 and 34 of these elements are present. Their long axes are radially disposed with respect to the center of the plate. The sutures between trapezohedral elements are inclined clockwise in proximal view. In cross-polarized light the central ring and the outer cycle of rectangular elements are bright. Four crenulate isogyres located 90 degrees from each other cut across the bright central ring when viewed from the distal side. SEM micrographs show three cycles of elements about a central perforation. An outer cycle of trapezohedral elements is connected by 80–85 rod-like elements to an inner cycle of sinistrally imbricate elements. With phase-contrast illumination the sinistrally imbricate elements are seen as the smooth ring and the rod-like elements are invisible. The sutures on the inner cycle of elements are inclined counterclockwise near the central perforation and clockwise near their periphery.

This species is distinguished from *B. spinosus* by the simpler construction of the rod elements, and the lack of secondary slits in the trapezohedral elements where they join the rods.

Hypotypes: Smithville D_1, (06.3;75.5), W.U.M.C. 000229; Size: 6 microns. Smithville A, SEM negative 5668; Size: 6 microns. SEM negative 5816; Size: 5 microns.

Occurrence: Previously reported from the lower Oligocene with questionable occurrence in the upper Eocene.

BLACKITES CREBER
(Deflandre)
n. comb.
Plate 5, figs. 25, 26

Rhabdolithus creber DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 157, pl. 12, figs. 31–33; text-figs. 81, 82; MANIVIT, 1961, p. 353, pl. 3, fig. 7; BOUCHÉ, 1962, p. 84, pl. 1, fig. 6.

Rhabdosphaera crebra (Deflandre). BRAMLETTE and SULLIVAN, 1961, p. 146, pl. 5, figs. 1–3; HAY and TOWE, 1963, p. 953, pl. 1, figs. 2–5; pl. 2, figs. 1–5; SULLIVAN, 1964, p. 185, pl. 7, fig. 3; SULLIVAN, 1965, p. 36, pl. 7, figs. 4, 5.

Rhabdolithes creber (Deflandre). HAY, MOHLER and WADE, 1966, p. 390; HODSON and WEST, 1970, p. 182, pl. 2, figs. 2, 3; pl. 3, fig. 3; text-fig. 3.

Blackites creber (Deflandre). STRADNER and EDWARDS, 1968, p. 29 (transfer invalid); PERCH-NIELSEN, 1971 a, p. 963, fig. 16 (transfer invalid).

Remarks: Rhabdoliths with a short spike surmounting a circular base plate. In the light microscope the base plate appears flat on the proximal side and gently rounded on the distal side. The spike has a collar structure at its base and gently tapers from that collar throughout most of its length, then abruptly comes to a point. In cross-polarized light with the long axis of the rhabdolith parallel to the polarizer, the base plate and spike are brightly illuminated with the collar only barely discernable.

Hypotype: Hurricane Shoals M (26.2; 74.2), W.U.M.C. 000230; Size: 7.5 X 3 microns.

Occurrence: Reported from the Paleocene and Eocene in North America and the Eocene in Europe and the Northwest Caucasus Mountains of the U.S.S.R.

BLACKITES SCABROSUS
(Deflandre)
Roth, 1970
Plate 5, fig. 23

Rhabdolithus scabrosus DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 158, pl. 12, fig. 30; text-fig. 85.

Rhabdosphaera scabrosa (Deflandre). BRAMLETTE and SULLIVAN, 1961, p. 147, pl. 5, fig. 11; SULLIVAN, 1965, p. 37; pl. 7, fig. 6; REINHARDT, 1967, p. 215, pl. 4, fig. 23; pl. 7, fig. 2.

Blackites scabrosus (Deflandre). ROTH, 1970, p. 858.

Remarks: This species is very similar to *B. tenuis* in its appearance under phase-contrast and in cross-polarized light but is distinguished from *B. tenuis* by its rugose surface.

Hypotype: Hurricane Shoals J (28.3; 73.7), W.U.M.C. 000231; Size: 23 X 5 microns.

Occurrence: Reported from the lower Eocene through the Oligocene in North America and Europe.

BLACKITES TENUIS
(Bramlette and Sullivan)
n. comb.

Plate 5, figs. 19–22
Plate 6, figs. 5, 7

Rhabdosphaera tenuis BRAMLETTE and SULLIVAN, 1961, p. 147; pl. 5, fig. 14; BENEŠOVÁ and HANZLÍKOVÁ, 1962, pl. 4, fig. 2; SULLIVAN, 1964, p. 186, pl. 7, fig. 4; SULLIVAN, 1965, p. 37, pl. 7, fig. 10; LEVIN and JOERGER, 1967, p. 169, pl. 2, fig. 16; RADOMSKI, 1968, p. 573, pl. 46, fig. 13; MARTINI, 1969b, p. 138, pl. 3, figs. 30, 31; HAQ, 1971b, p. 89, pl. 5, fig. 14; ?pl. 11, fig. 3.

PLATE 6

Magnification 4500 X

Figures Page

1, 2 *Transversopontis pulchra* (Deflandre) Haq 35
Proximal view, from Smithville A.

1. SEM negative 5823
2. SEM negative 5658

3, 4 *Transversopontis ocellatus* (Bramlette and Sullivan) n. comb. 34

3. Distal view, from Smithville A, SEM negative 5817.
4. Proximal view, from Smithville D_1, SEM negative 5817.

5, 7 *Blackites tenuis* (Bramlette and Sullivan) n. comb. 42
From Smithville A.

5. Distal view, SEM negative 5674
7. Proximal view, SEM negative 5689

6 *Transversopontis pulchriporus* (Reinhardt) n. comb. 39
Distal view, from Smithville A, SEM negative 5621.

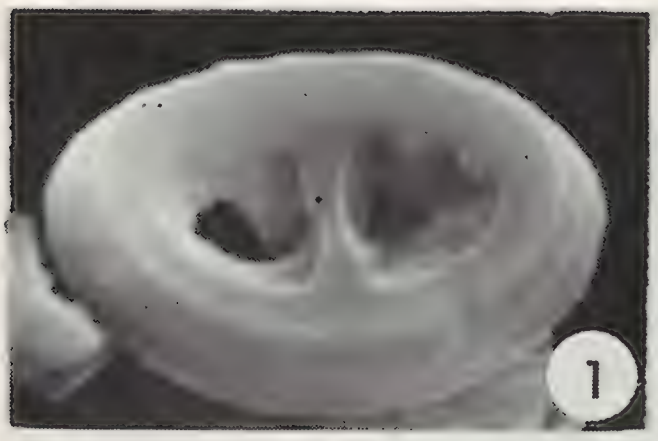
8 *Helicopontosphaera seminulum* (Bramlette and Sullivan) Roth 39
Proximal view, from Sabine River E, SEM negative 6471.

9, 10 *Blackites amplus* Roth and Hay 40
From Smithville A

9. Proximal view?, SEM negative 5668
10. Distal view, SEM negative 5816

11 *Braarudosphaera bigelowi* (Gran and Braarud) Deflandre 45
From Fort Bend County 6, 9490, SEM negative 6485.

12 *Braarudosphaera discula* Bramlette and Riedel 48
From Smithville A, TEM negative 1.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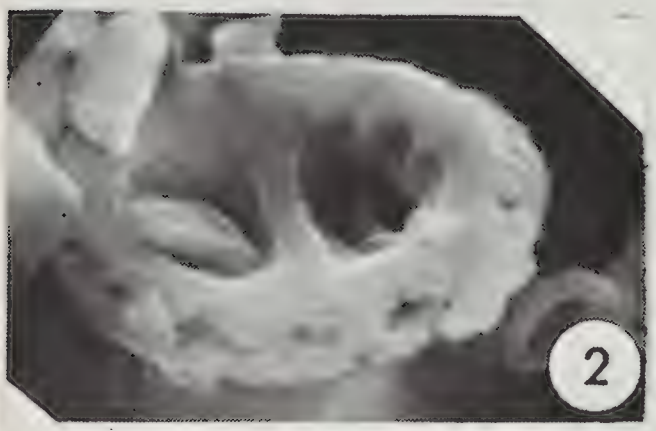
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PLATE 6

Rhabdolithes tenuis HODSON and WEST, 1970, p. 184, pl. 3, fig. 1.

Remarks: Rhabdoliths with a relatively small circular base plate which bears a long uniformly tapering stem. The stem terminates distally in a sharp point. Depending upon the orientation of the long axis with respect to the polarizer, two distinct morphologies can be observed. When parallel to the polarizer, the base plate appears to bear nodes and is joined to a collar which surrounds a uniformly tapering needle-like stem. No central canal is visible in this orientation. When the long axis is oriented parallel to the analyzer the collar and base plate appear fused and are seen as bright areas on either side of the rhabdolith. The stem gently flares and joins with these bright areas. The stem tapers gently to a sharp point at the distal end. In this position the stem appears twice as thick as when viewed parallel to the polarizer. In addition, the central canal is now clearly visible. The canal extends the length of the stem becoming narrower near the distal tip.

SEM micrographs of this species reveal the presence of three or possibly four cycles of morphologically different crystal elements making up the base plate. Based upon this information this species is transferred to the genus *Blackites*.

On the proximal side (Plate 6, figure 7), the outermost cycle of elements in the base plate consists of approximately 30 non-imbricate rectangular elements. The long axis of each element is radially arranged with respect to the center of the plate. The outer cycle of elements does not lie in the same plane as the remaining element, but is inclined to them at a small angle. This small inclination is responsible for the slightly concave appearance of the base plate in cross section.

Each rectangular element in the outer cycle is joined to three or sometimes four rods or plates that make up the second cycle of elements. The plates are radially arranged, extending inward and becoming more rod-like as they join the third cycle of elements. At the center of the plate each rod makes a sharp right-angle turn and extends up inside the stem.

The distal side of the base plate (Plate 6, figure 5) shows two outer cycles of elements that appear essentially the same in size and shape as those of the proximal side. However, the third cycle of elements consists of plates that are strongly sinistrally imbricate. The sutures between the plates are inclined clockwise. The inner portion of these plates appears to extend upward and forms a shallow ring around the base of the stem. This ring comes into contact with a cycle of sinistrally imbricate plates which make up the remainder of the collar. The upper plates of the collar are roughly twice as long as wide, and their long axis is parallel to the long axis of the stem.

It appears likely that only the two outermost cycles of elements are visible from both the proximal and the distal sides of the base plate. The rods of the third cycle of the proximal side run under the third cycle elements of the distal side. The shallow ring on the distal side may be formed by the rods extending through from the proximal side.

The stem consists of many long, thin and wide crystal laths. The long axis of the lath is aligned parallel to the long axis of the stem. The intermediate axis is radially arranged with respect to the center of the stem. The lath is approximately three times wider than thick and six times longer than wide.

Hypotypes: Hurricane Shoals M (20.3; 79.8), W.U.M.C. 000232; Size: 23 X 5 microns. Smithville A, SEM negative 5689; Size: 6 microns across base plate. SEM negative 5674; Size: 4.5 microns across base plate.

Occurrence: Reported from the Eocene and Oligocene in North America and the Eocene in Europe.

Genus RHABDOLITHES
Schmidt, 1870

Description: Centrally perforated subcircular to circular basal shields surmounted by a radial stem which is hollow. A collar may be present next to the shield.

Type Species: Rhabdosphaera claviger Murray and Blackman.

RHABDOLITHES GLADIUS
(Locker)
n. comb.

Rhabdosphaera gladius LOCKER, 1967, p. 766, pl. 1, fig. 8; pl. 2, fig. 12; MARTINI, 1969b, pl. 2, figs. 17, 18; MARTINI, 1971c, p. 741, pl. 2, figs. 8, 9.

Remarks: Rhabdoliths with a thick rounded base surmounted by a broad short spine. A collar is present where the spine joins the circular base. The spine is hollow, thins a little just above the collar and then thickens again before coming to a broadly rounded point. In cross-polarized light the spine and base are brightly illuminated. This species may belong in *Blackites,* however, it was not possible to examine the base plate with the electronmicroscope to determine the nature of its construction.

Occurrence: Reported from the middle Eocene in Germany.

RHABDOLITHES RUDIS
(Bramlette and Sullivan)
n. comb.
Plate 5, fig. 24

Rhabdosphaera rudis BRAMLETTE and SULLIVAN, 1961, p. 146, pl. 5, fig. 6; SULLIVAN, 1964, p. 185, pl. 7, figs. 5, 6; SULLIVAN, 1965, p. 37, pl. 7, fig. 2.

Remarks: Trapezohedral-shaped rhabdoliths with a thick circular base plate surmounted by a short but very wide stem. The stem is almost as wide as the base and is bisected by a narrow black line when viewed in cross-polarized light. The walls of the stem are very thick leaving only a narrow hollow canal. The surface of the stem is rugose. Stefan Gartner, Jr., suggested that this is *Zygrhablithus bijugatus* in his review of the manuscript.

Hypotype: Fort Bend County 6, 9490 (08.2; 77.1), W.U.M.C. 000233; Size: 6.5 X 4.5 microns.

Occurrence: Reported from the Paleocene and lower Eocene in California.

Family BRAARUDOSPHAERACEAE
Deflandre, 1947

Description: Coccolithophores bearing pentaliths. The coccosphere is composed of twelve pentaliths and has the form of a dodecahedron. Each pentalith consists of five distinct crystallites constructed of laminae of rhombohedral crystals stacked parallel to the base of the pentalith. The sutures between elements make angles of 72 degrees with each other. Living examples of *Braarudosphaera bigelowi* contain large chromatophores but do not possess a nucleus of flagellae.

Genus BRAARUDOSPHAERA
Deflandre, 1947

Description: Pentaliths with straight or curving outer margins. No perforations or depressions are present on the elements of the pentalith. Forms with straight margins have trapezohedral elements making up the pentalith.

Type Species: Braarudosphaera bigelowi (Gran and Braarud) Deflandre.

BRAARUDOSPHAERA BIGELOWI
(Gran and Braarud)
Deflandre, 1947
Plate 6, fig. 11
Plate 7, figs. 1, 2

Pontosphaera bigelowi GRAN and BRAARUD, 1935, p. 398, text-fig. 67.

Braarudosphaera bigelowi (Gran and Braarud). DEFLANDRE, 1947, p. 439, figs. 1–5; DEFLANDRE, 1950, p. 1156, text-figs. 1–4; KLUMPP, 1953, p. 380, fig. 2, nos. 1, 2; DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 165, pl. 10, figs. 8–13; pl. 13, figs. 7–9; BRAMLETTE and RIEDEL, 1954, p. 393, pl. 38, fig. 6a, b; MARTINI, 1958, p. 355, pl. 2, fig. 6; STRADNER, 1959, p. 482; text-figs. 63, 68; MARTINI, 1960, p. 73, pl. 8, fig. 1; MANIVIT, 1961, p. 354, pl. 4, fig. 1; *non* fig. 2; STRADNER *in* STRADNER and PAPP, 1961, p. 116, pl. 37, figs. 1–3; text-fig. 12–1; BRAMLETTE and SULLIVAN, 1961, p. 153, pl. 8, figs. 1a, b, 2–5; NARASIMHAN, 1961, p. 56, pl. 8, fig. 15; pl. 1, figs. 1, 2; BOUCHÉ, 1962, p. 85, pl. 4, figs. 1, 5; HAY and TOWE, 1962, p. 427; text-fig. 1; STRADNER, 1963, pl. 6, fig. 9; SULLIVAN, 1964, p. 188, pl. 8, figs. 1a, b; BYSTRICKÁ, 1964, p. 211, pl. 7, fig. 7; BONA, 1964, p. 127, pl. 14, fig. 1; COHEN, 1965, p. 31, pl. 6, figs. a–d; LEVIN, 1965, p. 268, pl. 42, figs. 4, 5; BLACK, 1965, p. 135, fig. 23; SULLIVAN, 1965, p. 39; HAY, MOHLER and WADE, 1966, p. 394; HAY and MOHLER, p. 1535, pl. 202, figs. 12, 16, 20; LEVIN and JOERGER, 1967, p. 170, pl. 3, figs. 5a–b; GARTNER and SMITH, 1967, p. 6, pl. 9, figs. 1–3; HAQ, 1968, p. 41, pl. 11, figs. 3, 4; RADOMSKI, 1968, p. 576, pl. 48, fig. 4; BOUDREAUX and HAY, 1969, p. 281, pl. 8, figs. 21–23; BYSTRICKÁ, 1969, p. 230, pl. 43, fig. 14; MARTINI, 1969a, p. 290, pl. 27, figs. 9,

PLATE 7

The long axis of each specimen is parallel to
the polarizer unless otherwise specified.

Magnification 1800 X
unless otherwise specified.

Figures Page

1, 2 *Braarudosphaera bigelowi* (Gran and Braarud) Deflandre 45
From Smithville A (01.4; 77.0), W.U.M.C. 000234.

1. Phase-contrast
2. Between crossed-polarizers

3, 4 *Blackites amplus* Roth and Hay 40
Distal view, from Smithville D_1 (06.3; 75.5), W.U.M.C. 000229.

3. Phase-contrast
4. Between crossed-polarizers

5, 6 *Micrantholithus ornatus* Sullivan 49
From Fort Bend County 6, 10180 (16.2; 75.4), W.U.M.C. 000237.

5. Phase-contrast
6. Between crossed-polarizers

7, 8 *Micrantholithus flos* Deflandre 49
From Smithville A (03.15; 76.9), W.U.M.C. 000236.

7. Phase-contrast
8. Between crossed polarizers

9, 10 *Pemma angulatum* Martini 50
From Smithville A.

9. Phase-contrast
10. Between crossed-polarizers

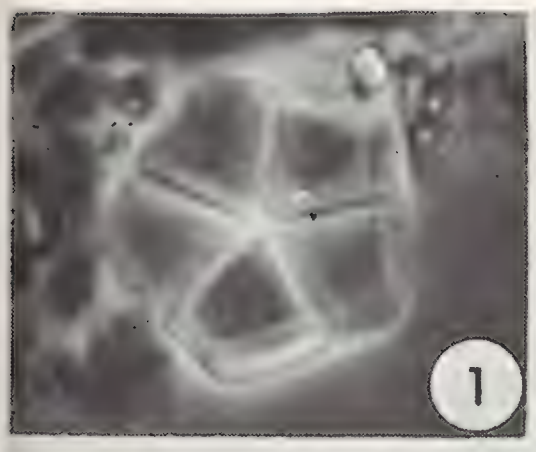
11, 12 *Micrantholithus procerus* Bukry and Bramlette 49
15, 16 Hypotype from Polk County 9, 5333 (22.5; 74.1), W.U.M.C. 000238.

11. Hypotype, phase-contrast
12. Hypotype, between crossed-polarizers
15. Side view, phase-contrast, 900 X
16. Side view, between crossed-polarizers, 900 X

13, 14 *Pemma basquense crassum* (Bouché) Bybell and Gartner 50
From Smithville A

13. Phase-contrast
14. Between crossed-polarizers

(continued next page)



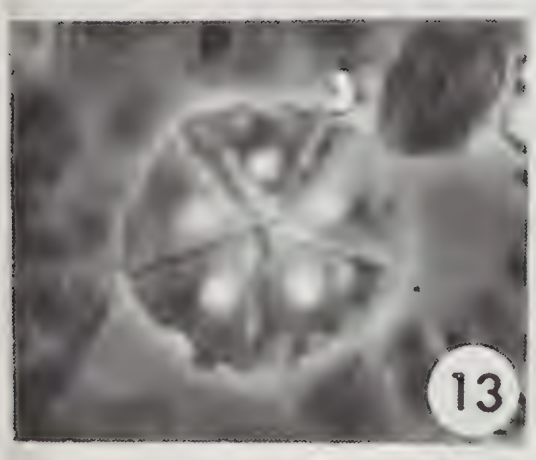


PLATE 7

17, 18 *Pemma bulbosus* (Bouché) n. comb. 51
From Smithville A

17. Phase-contrast
18. Between crossed-polarizers

19, 20 *Pemma basquense basquense* (Martini) Bybell and Gartner 50
From Hurricane Shoals J (15.8; 74.7), W.U.M.C. 000239.

19. Phase-contrast
20. Between crossed-polarizers

21, 22 *Pemma papillatum* Martini 51
Magnification 900 X
From Fort Bend County 6, 9490

21. Phase-contrast
22. Between crossed-polarizers

23, 24 *Pemma major* (Bouché) n. comb. 51
From Smithville A (20.2; 79.8), W.U.M.C. 000240.

23. Phase-contrast
24. Between crossed-polarizers

25 *Sphenolithus furcatolithoides* Locker 54
Side view, between crossed-polarizers, from Polk County 9, 5457 (24.8; 75.0), W.U.M.C.000241.

26 *Sphenolithus moriformis* (Bronnemann and Stradner) Bramlette and Wilcoxon . 54
Basal view, between crossed-polarizers, from Liberty County 12, 10960 (18.85; 75.1), W.U.M.C. 000242.

10; HODSON and WEST, 1970, p. 170; BARTOLINI, 1970, p. 152, pl. 1, fig. 1; PERCH-NIELSEN, 1971a, p. 942, fig. 1; HAQ, 1971a, p. 47, pl. 6, fig. 3; HAQ, 1971 b, p. 92, pl. 5, fig. 13; pl. 11, fig. 6; HAQ, 1971c, p. 121; PERCH-NIELSEN, 1971b, p. 59; RAMSAY, 1971, p. 206, pl. 4, fig. 2; BYBELL and GARTNER, 1972 [1973], p. 323, pl. 1, figs. 1, 2.

Remarks: Pentaliths made up of five separate crystalline elements. The complete pentalith has five flat sides which meet at angles of 120 degrees. Each element is trapezohedral in outline, having each of the three longer sides at least twice as long as the shortest side. Each flat side of the pentalith is composed of one short and one long trapezohedral leg which are part of two adjacent pentalith elements.

Hypotypes: Smithville A (01.4; 77.0), W.U.M.C. 000234; Size: 12.5 microns. Fort Bend County 6, 9490, SEM negative 6485; Size: 11 microns.

Occurrence: Reported from various parts of the world throughout the Cenozoic.

BRAARUDOSPHAERA DISCULA
Bramlette and Riedel, 1954
Plate 6, fig. 12

Braarudosphaera discula BRAMLETTE and RIEDEL, 1954, p. 394, pl. 38, fig. 7; BRAMLETTE and SULLIVAN, 1961, p. 153, pl. 8, figs. 6, 7; STRADNER *in* STRADNER and Papp, 1961, p. 117, text-fig. 12–3; SULLIVAN, 1964, p. 188, pl. 8, fig. 2; SULLIVAN, 1965, p. 39, pl. 8, figs. 1, 3; HAY and MOHLER, 1967, p. 1535, pl. 202, figs. 13–15; BYSTRICKÁ, 1969, p. 231,pl. 43, fig.

13; PERCH-NIELSEN, 1969, p. 57, pl. 7, figs. 1, 2; PERCH-NIELSEN, 1971a, p. 942, fig. 1; BYBELL and GARTNER, 1972 [1973], p. 323.

Braarudosphaera aff. *discula* (Bramlette and Riedel). RADOMSKI, 1968, p. 576, pl. 47, fig. 3; HAQ, 1971c, p. 121, pl. 17, fig. 3.

Braarudosphaera cf. *discula* Bramlette and Riedel. BILGÜTAY *et al.*, 1969, p. 173, pl. 3, fig. 6.

Remarks: Discoidal pentaliths without perforations on the pentalith elements. The peripheral surface of each segment is curved. The sutures between elements form angles of 72 degrees. Transmission electronmicrographs show the pentaliths to be made up of small rhombic elements.

Hypotype: Smithville A, Transmission electronmicrograph 1; Size: 10 microns.

Occurrence: Reported from the Paleocene through the lower and middle Eocene in various parts of the world.

Genus MICRANTHOLITHUS
Deflandre, 1950

Description: Pentaliths with V-shaped segments.

Type Species: Micrantholithus flos Deflandre.

MICRANTHOLITHUS FLOS
Deflandre, 1950
Plate 7, figs. 7, 8

Micrantholithus flos DEFLANDRE, 1950, p. 1158, text-fig. 8–11; DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 166, pl. 13, figs. 10, 11; text-figs. 113, 114; MARTINI, 1958, p. 356, pl. 1, fig. 2; STRADNER, 1959, p. 482; text-fig. 60; MARTINI, 1960, p. 74, pl. 8, fig. 4; BRAMLETTE and SULLIVAN, 1961, p. 155, pl. 9, fig. 8; MANIVIT, 1961, p. 355, pl. 4, fig. 3; MARTINI, 1961, p. 6, pl. 1, fig. 11; STRADNER *in* STRADNER and PAPP, 1961, p. 121, pl. 39, figs. 3, 4; text-fig. 12/9; BOUCHÉ, 1962, p. 87, pl. 2, figs. 1, 2; text-figs. 13, 14; HAY and TOWE, 1962, p. 427, fig. 6; SULLIVAN, 1964, p. 189, pl. 9, fig. 5; SULLIVAN, 1965, p. 40, pl. 9, figs. 1–3; BUKRY and KENNEDY, 1969, p. 42, fig. 4, no. 1; HAQ, 1971b, p. 91; HAQ, 1971c, p. 121, pl. 6, fig. 3; PERCH-NIELSEN, 1971a, p. 942, fig. 1.

Micrantholithus sp.. HAY and MOHLER, 1967, p. 1535, pl. 202, figs. 17–19.

Remarks: Pentaliths constructed of V-shaped segments. Lateral thickenings occur along both sides of the sutures. A narrow zone along the periphery of the segments is not thickened, producing a thin shelf.

Specimens of this species in the Weches Formation have only a narrow zone along the periphery of the segments that is not thickened. Most specimens of this species figured in the literature show a triangular area that is not thickened. The Weches specimens have been assigned to this species, even though they lack the thinned triangular area, because they do not have the thin tenuous rays characteristic of *M. vesper.*

Hypotype: Smithville A (03.15; 76.9), W.U.M.C. 000236; Size: 10 microns.

Occurrence: Reported from the Paleocene and Eocene in various parts of the world.

MICRANTHOLITHUS ORNATUS
Sullivan, 1965
Plate 7, figs. 5, 6

Micrantholithus ornatus SULLIVAN, 1965, p. 40, pl. 8, fig. 7; PERCH-NIELSEN, 1971a, p. 942, fig. 1; BYBELL and GARTNER, 1972 [1973], p. 325, pl. 1, figs. 15, 16.

Remarks: Pentalith with V-shaped segments. Near the ends of the arms of the "V" lateral nodes occur, which extend into the inter-arm area. Beyond the nodes the arms thin and terminate in a small rounded node.

Hypotype: Fort Bend County 6, 10180 (16.2; 75.4), W.U.M.C. 000237; Size: 12 microns.

Occurrence: Reported from the early middle Eocene in Alabama and California, and the upper Eocene in Hungary.

MICRANTHOLITHUS PROCERUS
Bukry and Bramlette, 1969
Plate 7, figs. 11, 12, 15, 16

Micrantholithus procerus BUKRY and BRAMLETTE, 1969, p. 136, pl. 2, figs. 12–15; GARTNER, 1971, figs. 1, 4; PERCH-NIELSEN, 1971a, p. 942, fig. 1; BYBELL and GARTNER, 1972 [1973], p. 325, pl. 3, figs. 1–6.

Remarks: Pentaliths with V-shaped segments. The indentation that gives the V-shape to the segments is not very pronounced. In plan view the outline of this species appears much like that of *Pemma angulatum.* The peripheral terminations of the segments are broadly rounded. No depressions are present on the segments of the pentalith. In side view this species is from one to nearly two times longer than it is wide. The body of the pentalith tapers from a flat base to a broadly rounded termination.

Hypotype: Polk County 9, 5333 (22.5; 74.1), W.U.M.C. 000238; Size: 8 microns.

Occurrence: Reported from the early middle Eocene in various parts of the world.

Genus PEMMA
Klumpp, 1953

Description: Pentaliths with a circular or pentagonal outline having a depression or perforation in each of the five segments.

Type Species: Pemma rotundum Klumpp.

PEMMA ANGULATUM
Martini, 1959
Plate 7, figs. 9, 10
Plate 8, fig. 4

Pemma angulatum MARTINI, 1959b, p. 416, pl. 1, figs. 1–4; GARTNER and SMITH, 1967, p. 6, pl. 11, fig. 1; LOCKER, 1968, pl. 2, fig. 13; ACHUTHAN and STRADNER, 1969, p. 8, pl. 5, fig. 9; GARTNER, 1971, figs. 4, 5; HAQ, 1971a, p. 45, pl. 7, figs. 5–7; PERCH-NIELSEN, 1971a, p. 942, fig. 1.

Remarks: Pentaliths with a peripheral notch located midway between the sutures of each segment. That portion of the pentalith segment between the notch and the suture terminates peripherally in a nearly flat surface. The flat terminations give this species the appearance of having five flat sides. Each flat side is made up of portions of two segments. Between the peripheral notch and the apex of each pentalith segment a nearly circular depression is seen with phase-contrast illumination.

The flat sides of this species distinguish it from other members of the genus.

Hypotype: Smithville A, SEM negative 5619; Size: 12 microns.

Occurrence: Reported from the Eocene in North America and Europe.

PEMMA BASQUENSE BASQUENSE
(Martini)
Bybell and Gartner, 1972 [1973]
Plate 7, figs. 19, 20

Micrantholithus basquensis MARTINI, 1959b, p. 417, pl. 1, figs. 9–12; SULLIVAN, 1965, p. 39, pl. 8, figs. 4, 5; BILGUTAY *et al.*, 1969, p. 174, pl. 5, figs. 1–4; GARTNER, 1971, fig. 4; PERCH-NIELSEN, 1971a, p. 942, fig. 1; PERCH-NIELSEN, 1971b, p. 59, pl. 56, fig. 1.

Micrantholithus basquensis basquensis Martini. BOUCHÉ, 1962, p. 85, pl. 2, fig. 11.

Micrantholithus cf. *basquensis* Martini. ACHUTHAN and STRADNER, 1969, p. 7, pl. 5, figs. 7, 8.

Pemma basquense basquense (Martini). BYBELL and GARTNER, 1972 [1973], p. 325, pl. 3, *non* figs. 7–14.

Pemma stradneri (Chang). BYBELL and GARTNER, 1972 [1973], p. 330, pl. 5, figs. 1–4.

Remarks: Circular pentaliths bearing a diamond-shaped depression on each segment. The outline of the specimen is regularly undulatory. The undulations are produced by thickenings along the sutures which extend beyond the periphery of the pentalith body, and one or two protrusions located along the periphery of the pentalith between the sutures of each segment.

The length of the marginal protrusions distinguishes this species. All protrusions are the same length. In *P. stradneri* the protrusions between the sutures are longer than those along the sutures.

Hypotype: Hurricane Shoals J (15.8; 74.7), W.U.M.C. 000239; Size: 7 microns.

Occurrence: Reported from the middle Eocene in North America and the middle and upper Eocene in Europe.

PEMMA BASQUENSE CRASSUM
(Bouché)
Bybell and Gartner, 1972 [1973]
Plate 7, figs. 13, 14
Plate 8, figs. 2, 3

Micrantholithus basquensis Martini. BRAMLETTE and SULLIVAN, 1961, pl. 8, figs. 14, 15;

LEVIN and JOERGER, 1967, p. 170, pl. 3, fig. 10; GARTNER, 1971, fig. 4; PERCH-NIELSEN, 1971a, p. 942, fig. 1; PERCH-NIELSEN, 1971b, p. 59, pl. 56, fig. 1.

Micrantholithus basquensis crassus BOUCHÉ, 1962, p. 85, pl. 2, figs. 3, 9, 10.

Pemma basquense crassum (Bouché). BYBELL and GARTNER, 1972 [1973], p. 326, pl. 4, figs. 1–6.

Remarks: Circular pentaliths bearing a large diamond-shaped depression on each segment. An indentation is present midway between sutures. This gives each segment of the pentalith a bilobate periphery. The indentation is joined to the central depression by a narrow valley produced by a reduction in the thickness of the pentalith in this area. The pentalith is made up of laminae stacked parallel to each other and perpendicular to the sutures.

Pemma basquense crassum is distinguished from *P. b. basquense* by the lack of protrusions at, and midway between, the sutures. The periphery of *P. b. crassum* is bilobate between sutures with a narrow valley connecting the peripheral indentation to the diamond-shaped central depression. In *P. bulbosus* this valley is much wider and the peripheral indentation deeper. The side walls of the valley in *P. bulbosus* extend to the sutures, giving the area along the sutures a rounded appearance.

Hypotype: Smithville A, SEM negatives 5673 and 5677; Size: 9 microns.

Occurrence: Reported from the middle Eocene in various parts of the world.

PEMMA BULBOSUS
(Bouché)
n. comb.
Plate 7, figs. 17, 18
Plate 8, fig. 8

Micrantholithus bulbosus BOUCHÉ, 1962, p. 87, pl. 2, figs. 4–7, text-fig. 12; PERCH-NIELSEN, 1971a, p. 942, fig. 1.

Remarks: Circular pentalith bearing a large depression on each segment. The depressions open to a peripheral indentation by way of a rather wide valley. The segments are bilobate between the sutures, but the lobes are smaller and the valley wider than in *Pemma basquense crassum.* The apex of the depression is located further from the apex of the pentalith segments than in *P. b. crassum* or *P. b. basquense.*

Pemma bulbosus is distinguished from *P. b. basquense* and *P. b. crassum* by its subcircular rather than diamond-shaped depressions and the greater distance from the apex of pentalith segments to the depressions. *P. b. crassum* does not have as wide a valley joining the central depression to the periphery as does *P. bulbosus* but it does have larger lobes between sutures.

Hypotype: Smithville A, SEM negative 5672; Size: 7 microns.

Occurrence: Reported from the middle Eocene in France.

PEMMA MAJOR
(Bouché)
n. comb.
Plate 7, figs. 23, 24

Micrantholithus parasiensis major BOUCHÉ, 1962, p. 86, pl. 2, figs. 17, 19, 20, 21, 25; text-fig. 11.

Remarks: Circular pentaliths bearing a diamond-shaped depression on each segment. The outline of the specimen is gently undulatory. The undulations are produced by thickenings along the sutures which extend a short distance beyond the periphery of the pentalith body. Two short, broadly rounded scallops appear between the sutures. Each segment thus bears two broad scallops and a less rounded, narrower protrusion along each suture. Specimens are 9 microns across or larger.

The nearly equal length of the protrusions and scallops distinguish this species from *Pemma stradneri* where the protrusions between sutures are longer than those at the sutures. In *P. b. basquense* the protrusions are narrower and more angular than those of *P. major.*

Hypotype: Smithville A (20.2; 79.8), W.U.M.C. 000240; Size: 9 microns.

Occurrence: Reported from the middle Eocene of the Paris Basin, France.

PEMMA PAPILLATUM
Martini, 1959
Plate 7, figs. 21, 22
Plate 8, fig. 5

Pemma papillatum MARTINI, 1959, p. 139, fig. 1; STRADNER, 1959a, p. 487, figs. 67, 68; STRADNER *in* STRADNER and PAPP, 1961, p. 120, pl. 38, figs. 4–6; *non* figs. 2, 3; *non* text-fig. 12–7; LEVIN, 1965, p. 269, pl. 42, figs. 7, 8. LEVIN and JOERGER, 1967, p. 171, pl. 3, fig. 11; GARTNER and SMITH, 1967, p. 6, pl. 10, figs. 1–3a, b; STRADNER, 1969, p. 666, pl. 6, figs. 6, 7; GARTNER, 1971, figs. 1, 2, 4, 5; HAQ, 1971a, p. 45, pl. 6, figs. 5–7; pl. 7, figs. 3, 4; pl. 8, figs. 2, 4, 5; PERCH-NIELSEN, 1971a, p. 942, fig. 1; BYBELL and GARTNER, 1972 [1973], p. 328, pl. 1, figs. 17–20.

Remarks: Circular pentalith with a subcircular depression on each segment. The periphery bears 20 nodes, four to each segment. The nodes distinguish this species from other members of the genus.

Hypotype: Fort Bend County 6, 9490, SEM negative 5907; Size: 14 microns.

Occurrence: Reported from the middle and upper Eocene in various parts of the world and the lower and middle Eocene in Mexico.

PEMMA ROTUNDUM
Klumpp, 1953
Plate 8, fig. 1
Plate 9, figs. 1, 2

Pemma rotundum KLUMPP, 1953, p. 381, pl. 16, fig. 3; text-fig. 2, 3; MARTINI, 1958, p. 355, pl. 2, fig. 7; MARTINI, 1959b, pl. 1, figs. 5a, 6–8; STRADNER, 1959, p. 487, text-fig. 66; MARTINI, 1960, p. 74, pl. 8, fig. 6; MARTINI, 1961, p. 7; STRADNER *in* STRADNER and

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PLATE 8

Magnification 4500 X

Figures — Page

1 *Pemma rotundum* Klumpp 52
Basal view, from Smithville A, SEM negative 5681.

2, 3 *Pemma basquense crassum* (Bouché) Bybell and Gartner 50
From Smithville A

2. Top view, SEM negative 5673
3. Top view, SEM negative 5677

4 *Pemma angulatum* Martini 50
Basal view, from Smithville A, SEM negative 5619.

5 *Pemma papillatum* Martini 51
Basal view, from Fort Bend County 6, 9490, SEM negative 5907.

6, 7 *Neococcolithes dubius* (Deflandre) Black 70
Distal view, from Smithville D_1.

6. SEM negative 5819
7. SEM negative 5883

8 *Pemma bulbosus* (Bouché) n. comb. 51
Top view, from Smithville A, SEM negative 5672.

9, 10 *Trochoaster simplex* Klumpp 55
From Smithville A.

9. Frontal view, SEM negative 5824.
10. Rear view, SEM negative 5880

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PLATE 8

PAPP, 1961, p. 119, pl. 38, fig. 1a, b; text-fig. 12–6; HAY and TOWE, 1962, p. 427; text-figs. 4, 5; COHEN, 1965a, p. 31; pl. 6, fig. e; HODSON and WEST, 1970, p. 172, pl. 1, fig. 3; HAQ, 1971, p. 46, pl. 7, fig. 10; PERCH-NIELSEN, 1971a, p. 942, fig. 1; PERCH-NIELSEN, 1971b, p. 60; pl. 56, fig. 5, 6. BYBELL and GARTNER, 1972 [1973], p. 330.

Remarks: Circular pentaliths with only slight irregularities in the periphery of the segments. A circular depression is located near the apex of each segment.

The nearly circular outline of the species distinguishes it from other members of the genus.

Hypotype: Smithville A, SEM negative 5681; Size: 10 microns.

Occurrence: Reported from the middle Eocene in various parts of the world and the middle and upper Eocene in Germany and Hungary.

Family SPHENOLITHACEAE
Deflandre, 1952

Description: Beehive or wedge-shaped calcium carbonate objects composed of spines set on a base composed of multiple elements.

Genus SPHENOLITHUS
Deflandre, 1954

Description: Beehive or wedge-shaped calcium carbonate objects consisting of a distal, single or bifurcating spine constructed of rod- or blade-like elements set on the convex side of a concave proximal shield. The proximal shield is constructed of rod-like to tabular elements radiating from a point, and is more or less circular.

Type Species: Sphenolithus radians Deflandre.

SPHENOLITHUS FURCATOLITHOIDES
Locker, 1967
Plate 7, fig. 25

Sphenolithus furcatolithoides LOCKER, 1967, p. 363, pls. 14–16; text-figs. 7, 8; GARTNER, 1971, figs. 1, 2, 4, 5; MARTINI, 1971c, p. 743; PERCH-NIELSEN, 1971a, p. 963, fig. 17; PERCH-NIELSEN, 1971b, p. 53, pl. 49, figs. 1–4; RAMSAY, 1971, p. 201, pl. 2, figs. 6, 7; ROTH, BAUMANN, and BARTOLINO, 1971, fig. 5.

Remarks: Sphenoliths with two prominent apical spines, each of which consists of four blade-like elements. The apical spines taper towards the distal end. Cycles of lateral elements are present between the apical spines and the proximal shield. The concave proximal shield consists of a single cycle of eight to ten tabular-shaped elements.

Sphenolithus furcatolithoides is referable to "morphotype one" of this genus (Roth, Franz, and Wise, Jr., 1971), which also contains *S. radians, S. pseudoradians,* and *S. heteromorphus.*

Hypotype: Polk County 9, 5457 (24.8; 75.0), W.U.M.C. 000241; Size: 6 X 2.5 microns.

Occurrence: Reported from the middle and early upper Eocene in various parts of the world.

SPHENOLITHUS MORIFORMIS
(Bronnimann and Stradner)
Bramlette and Wilcoxon, 1967
Plate 7, fig. 26

Nannoturbella moriformis BRONNIMANN and STRADNER, 1960, p. 368, figs. 11–16; (Erdoel-Zeitschrift, v. 76).

Sphenolithus pacificus MARTINI, 1965, p. 407, pl. 36, figs. 7–10.

Sphenolithus moriformis (Bronnimann and Stradner). BRAMLETTE and WILCOXON, 1967, p. 124, pl. 3, figs. 1–6; RADOMSKI, 1968, p. 558, pl. 43, figs. 19, 20; ROTH, 1970, p. 870, pl. 14, figs. 3, 4; GARTNER, 1971, figs. 4, 5; HAQ, 1971a, p. 33; HAQ, 1971b, p. 92, pl. 13, figs. 9, 10; HAQ, 1971c, p. 123, pl. 1, figs. ?7, 14, 25, 26; pl. 2, figs. 9, 10; pl. 3, figs. 5–9, PERCH-NIELSEN, 1971a, p. 963, fig. 17; PERCH-NIELSEN, 1971b, p. 53, pl. 49, figs. 5–10; ROTH, BAUMANN, BERTOLINO, 1971, figs. 5, 7, 8; ROTH, FRANZ, WISE, JR., 1971, p. 1105, pl. 5, figs. 4–6.

Remarks: Sphenoliths with many spines radiating from a concave proximal area. Under phase-contrast illumination the distal side reveals many elements radially disposed about the median axis of the sphenolith. In cross-polarized light four brightly illuminated trianguloid areas separated by extinction isogyres are observed.

Specimens of this species appear very much like those figured by Bramlette and Wilcoxon (1967).

Hypotype: Liberty County 12, 10960 (18.85; 75.1), W.U.M.C. 000242; Size: 5 microns.

Occurrence: Reported from the Paleocene to the Miocene in many regions of the world.

SPHENOLITHUS OBTUSUS
Bukry, 1971

Sphenolithus obtusus BUKRY, 1971, p. 321, pl. 6, figs. 1–9.

Remarks: The specimens encountered in the Weches Formation are very similar to those figured by Bukry (1971). *Sphenolithus obtusus* appears to belong to "morphotype one" or "three" of this genus (Roth, Franz, and Wise, Jr., 1971). Exact assignment cannot be made because electron micrographs are not available for study.

Occurrence: Reported from late middle Eocene sediments of Horizon Ridge, northwestern Pacific Ocean.

SPHENOLITHUS RADIANS
Deflandre, 1952
Plate 9, figs. 3, 4.

Sphenolithus radians DEFLANDRE, 1952, p. 466, fig. 363; DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 163, pl. 12, figs. 36–38; text-figs. 109–112; BRAMLETTE and SULLIVAN, 1961, p. 166, pl. 14, figs. 6–8; MANIVIT, 1961, p. 354, pl. 3, figs. 9, 10; SULLIVAN, 1964, p. 194, pl. 9, fig. 10; COHEN, 1965a, p. 35, pl. 5, figs. n–p; SULLIVAN, 1965, p. 45, pl. 11, fig. 3; RADOMSKI, 1968, p. 588, pl. 46, fig. 14; CLOCCHIATTI, 1971, p. 65, pl. 23, fig. 5; GARTNER, 1971, figs. 1, 4, 5; HAQ, 1971a, p. 34, pl. 10, fig. 8; MARTINI, 1971c, p. 743; PERCH-NIELSEN, 1971a, p. 963, fig. 17; PERCH-NIELSEN, 1971b, p. 53, pl. 47, figs. 1–9; pl. 48, figs. 1–7; ROTH, BAUMANN, and BERTOLINO, 1971, fig. 8; ROTH, FRANZ, and WISE, JR., 1971, p. 1102, pl. 1, figs. 1, 2.

Remarks: Sphenoliths with a prominent rectangular base surmounted by a tapering apical spine. Electronmicrographs have shown the base to consist of a labyrinth composed of radially disposed wedge-shaped elements surmounted by four to seven blade-like segments that make up the apical spine.

Hypotype: Fort Bend County 6, 10180 (14.8; 75.4), W.U.M.C. 000243; Size: 5 X 3.5 microns.

Occurrence: Reported from the Paleocene through the Oligocene in various parts of the world.

Family LITHOSTROMATIONACEAE
Deflandre, 1959

Description: Forms related to *Lithostromation* that have similar faces on both sides.

Genus TROCHOASTER
Klumpp, 1953

Description: Biconvex stellate body of ortholithid microstructure bearing six or twelve rays. The equatorial shape is hexagonal or circular which distinguishes the genus from *Lithostromation,* which has a three-sided equatorial shape.

Type Species: Trochoaster simplex Klumpp.

TROCHOASTER SIMPLEX
Klumpp, 1953
Plate 8, figs. 9, 10
Plate 9, fig. 8

Trochoaster simplex KLUMPP, 1953, p. 385, pl. 16, fig. 7; MARTINI, 1958, p. 368, pl. 5, fig. 25; MARTINI and STRADNER, 1960, p. 269, fig. 19; STRADNER and PAPP, 1961, p. 4, fig. 14–3; pl. 42, fig. 4; BOUCHÉ, 1962, p. 91–92, pl. 4, fig. 6; LEVIN, 1965, p. 271, pl. 43; figs. 7–9; LEVIN and JOERGER, 1967, p. 171, pl. 3, figs. 20–21; HODSON and WEST, 1970, p. 170; PERCH-NIELSEN, 1971a, p. 956, fig. 12; PERCH-NIELSEN, 1971b, p. 58, pl. 57, fig. 8.

Trochoaster duplex KLUMPP, 1953, p. 385, pl. 16, fig. 10.

Polycladolithus stellaris STRADNER, 1959, p. 487, figs. 74, 75, 77 e–h.

Remarks: Forms encountered in the Weches Formation have six rays extending beyond the central biconvex body. In frontal view the equatorial outline between rays is hexagonal. The surface of the biconvex body consists of a small central window. Six ridges radiate outward from the walls of the windows. The rays are connected by a crudely annular cycle of ridges spanning the inter-ray areas, producing six additional windows. Three windows are equal in size to the central window and alternate with larger windows.

PLATE 9

The long axis of each specimen is parallel to the polarizer unless otherwise specified.

Magnification 1800 X

Figures Page

1, 2 *Pemma rotundum* Klumpp 52
From Smithville A

1. Phase-contrast
2. Between crossed-polarizers

3, 4 *Sphenolithus radians* Deflandre 55
Between crossed-polarizers, Hypotype from Fort Bend County 6, 10180 (14.8; 75.4), W.U.M.C. 000243.

5 *Discoaster binodosus binodosus* Martini 59
Phase-contrast, from Fort Bend County 6, 9490 (04.1; 76.4), W.U.M.C. 000247.

6 *Discoaster binodosus hirundinus* Martini 60
Phase-contrast, from Polk County 9, 5333 (27.8; 80.2), W.U.M.C. 000248.

7 *Trochoaster radiatus* Locker 58
Phase-contrast, from Hurricane Shoals J (14.7; 80.8), W.U.M.C. 000244.

8 *Trochoaster simplex* Klumpp 55
Frontal view, phase-contrast, from Smithville A

9 *Discoaster deflandrei* Bramlette and Riedel 60
Phase-contrast, from Fort Bend County 6, 10180 (15.8; 75.4), W.U.M.C. 000249.

10 *Discoaster lodoensis* Bramlette and Riedel 64
Phase-contrast, from Sabine River E.

11 *Discoaster aster* Bramlette and Riedel 58
Phase-contrast, from Fort Bend County 6, 9490 (09.1, 77.2,), W.U.M.C. 000245.

12 *Discoaster barbadiensis* Tan 59
Convex side, phase-contrast, from Polk County 9, 5333 (21.0; 73.5), W.U.M.C. 000246.

13 *Discoaster diastypus* Bramlette and Sullivan 60
Phase-contrast, from Austin County 5, 9625 (29.7; 75.5), W.U.M.C. 000250.

14 *Discoaster sublodoensis* Bramlette and Sullivan 65
Phase-contrast, from Fort Bend County 6, 10180 (15.2; 74.9), W.U.M.C. 000256.

(continued next page)

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PLATE 9

15 *Discoaster mirus* Deflandre 64
Phase-contrast, from Sabine River E.

16 *Discoaster saipanensis* Bramlette and Riedel 65
Phase-contrast, from Hardin County 11, 8271 (02.7; 74.4), W.U.M.C. 000254.

17 *Discoaster tumescens* Noël 68
Phase-contrast, from Smithville A.

18 *Discoaster lenticularis* Bramlette and Sullivan 64
Phase-contrast, from Fort Bend County 6, 10180 (12.6; 75.4), W.U.M.C. 000253.

The ridges which border the larger windows are directed outward toward the periphery forming a V, the apex of which is located at the center of the inter-ray area.

The opposite side shows a small central window surrounded by six radial rays. Three large windows and three small depressions alternate in inter-ray areas. Specimens were free of overgrowths of calcite; only a few showed broken rays.

Hypotype: Smithville A, SEM negatives 5824 and 5880; Size: 11.5 microns.

Occurrence: Reported from the Eocene through the middle Miocene in various parts of the world.

TROCHASTER RADIATUS
Locker, 1965
Plate 9, fig. 7

Trochoaster radiatus LOCKER, 1965, p. 1258, pl. 2, fig. 1; text-fig. 1; PERCH-NIELSEN, 1971a, p. 956, fig. 12.

Remarks: Biconvex body of labyrinthic construction. Three circular openings approximately 1.5 microns across are disposed at 120 degrees to each other about the center of the top side. The openings are separated by a three-armed ridge at the center and bordered by annular ridges which give rise to twelve radially disposed rays. The radial rays extend beyond the equator of the body, protruding approximately 1 micron. The opposite side of the body has the arms of the central bridge rotated 60 degrees relative to those of the top side.

Hypotype: Hurricane Shoals J (14.7; 80.8), W.U.M.C. 000244; Size: 10 microns.

Occurrence: Reported from the upper Eocene in north central Germany.

Family DISCOASTERACEAE
Tan, 1927

Description: Rosette or star-shaped calcareous discs (asteroliths) of radiating construction with orthol ithid optical features in cross-polarized light. The discs may be ornamented with stars, knobs, ridges, sutures or pores. Some forms may bear stems on one or both sides of the disc.

Genus DISCOASTER
Tan, 1927

Description: Rosette or star-shaped asteroliths with or without simple stems on one or both sides. In cross-polarized light the specimen is extinct in all positions in plan view.

Type Species: *Discoaster pentaradiatus* Tan.

DISCOASTER ASTER
Bramlette and Riedel, 1954
Plate 9, fig. 11

Discoaster aster BRAMLETTE and RIEDEL, 1954, p. 400, pl. 39, fig. 7; BRAMLETTE, 1957, p. 249, pl. 61, fig. 4; STRADNER, 1959, p. 1088, fig. 29; NARASIMHAN, 1961, p. 70, pl. 2, fig. 2; STRADNER and PAPP, 1961, p. 63, pl. 1, fig. 1–7; text-fig. 8–1; LEVIN, 1965, p. 270, pl. 43, fig. 3; LEVIN and JOERGER, 1967, p. 171, pl. 3, figs. 14, 15; RADOMSKI, 1968, p. 578; BYSTRICKÁ, 1969b, pl. 17, fig. 14; BARTOLINI and PARINI, 1969, p. 86, pl. 8, fig. 4; CLOCCHIATTI, 1971, p. 71, pl. 24, figs. 3, 4; pl. 25, fig. 1; pl. 26, fig. 1; text-fig. 12. PERCH-NIELSEN, 1971a, p. 951, fig. 9.

Remarks: Planar stellate asterolith usually of five or six rays. The free length of the rays is

one to two times greater than the radius of the central disc. The rays are broad with rounded, blunt ends. The sides of the ray are often rugose giving a saw-tooth appearance to some rays. The rays may be straight throughout their length or slightly curved. The width of separation between rays is highly variable. The inter-ray area is subangular to rounded. No button or star has been observed on the central disc.

Hypotype: Fort Bend County 6, 9490 (09.1; 77.2), W.U.M.C. 000245; Size: 7 microns.

Occurrence: Reported from the Tertiary and possibly Quaternary of various parts of the world.

DISCOASTER BARBADIENSIS
Tan, 1927
Plate 9, fig. 12
Plate 10, fig. 1

Discoaster barbadiensis TAN, 1927, p. 119; BERSIER, 1939, p. 238, figs. 22–29; BRAMLETTE and RIEDEL, 1954, p. 398, pl. 39, fig. 5a, b; BRAMLETTE, 1957, pl. 61, fig. 10; MARTINI, 1958, p. 366, pl. 5, fig. 24a–c; STRADNER, 1959, p. 1082, fig. 2; STRADNER, 1959, p. 484, fig. 28; MARTINI, 1960, p. 76, pl. 8, fig. 10; STRADNER and PAPP, 1961, p. 95, pl. 28, figs. 1, 2; text-figs. 9–7, 18–6, 24–3; BRAMLETTE and SULLIVAN, 1961, p. 158, pl. 11, fig. 2; MANIVIT, 1961, p. 369, pl. 10, figs. 1–5; NARASIMHAN, 1961, p. 73, pl. 8, fig. 16; *non* HAY and TOWE, 1962, p. 515, pl. 10, figs. 3, 5; BOUCHÉ, 1962, p. 89, pl. 3, figs. 1–4; text-figs. 16, 17 and c; STRADNER, 1962, p. 181, pl. 2, figs. 6, 7; SULLIVAN, 1964, p. 189, pl. 10, figs. 5, 6; COHEN, 1965a, p. 32, pl. 7, figs. a–d; LEVIN and JOERGER, 1967, p. 172, pl. 3, fig. 17; HAQ, 1967, p. 63, figs. 1, 2; HAY *et al.*, 1967, pl. 1, figs. 9–11: LOCKER, 1968, p. 224, pl. 1, fig. 13; RADOMSKI, 1968, pl. 47, fig. 11; ACHUTHAN and STRADNER, 1969, p. 5, pl. 4, figs. 1, 2; BILGÜTAY *et al.*, 1969, p. 173, pl. 3, fig. 4; BYSTRICKÁ, 1969a, p. 207, pl. 40, figs. 2–4; BYSTRICKÁ, 1969b, p. 81, pl. 11, figs. 1–11; pl. 17, figs. 1–13; HAQ, 1969, p. 6, pl. 3, figs. 4–7; text-fig. 1A; HONJO and MINOURA, 1969, p. 166, figs. 3, 4; MARTINI, 1969a, pl. 29, fig. 9; HOFFMANN, 1970, p. 11, pl. 1, figs. 1–4; HODSON and WEST, 1970, p. 168, pl. 1, figs. 2, 5; CLOCCHIATTI, 1971, p. 72, pl. 30, figs. 1–4; GARTNER, 1971, figs. 1, 4, 5; HAQ, 1971a, p. 35, pl. 8, figs. 6, 7; pl. 10, figs. 11, 12; HAQ, 1971b, p. 89, MARTINI, 1971c, p. 743, PERCH-NIELSEN, 1971a, p. 951, fig. 8; PERCH-NIELSEN, 1971b, p. 61, pl. 51, fig. 5; RAMSAY, 1971, p. 206, pl. 1, fig. 5; ROTH, BAUMANN and BERTOLINO, 1971, figs. 5–9.

Remarks: Concavo-convex discoaster with 9–14 petal-like rays. The rays are joined throughout most of their length. At the periphery the terminations of the rays are rounded, blunt or slightly pointed. The convex side of the asterolith bears a small central knob, the concave side a short stem.

The knob on the convex side of *Discoaster barbadiensis* is smaller and less prominent than the knob found on the convex side of *D. elegans.* The periphery of *D. elegans* is more deeply serrate giving the rays long, tapering terminations. Annular rings or ridges are concentrically arranged about the center of *D. elegans;* no such ridges are present in *D. barbadiensis. D. barbadiensis* shows less relief in Canada balsam than *D. elegans.*

Hypotypes: Polk County 9, 5333 (21.0; 73.5), W.U.M.C. 000246; Size: 8 microns. Fort Bend County 6, 9490, SEM negative 5792; Size: 15 microns.

Occurrence: Reported from the Eocene in various parts of the world.

DISCOASTER BINODOSUS BINODOSUS
Martini, 1958
Plate 9, fig. 5
Plate 10, fig. 6

Discoaster binodosus binodosus MARTINI, 1958, p. 362, pl. 4, fig. 18; PERCH-NIELSEN, 1971a, p. 951, fig. 10; PERCH-NIELSEN, 1971b, p. 61, pl. 52, fig. 6.

Discoaster binodosus MARTINI, 1959, p. 138; STRADNER, 1959a, p. 1084, fig. 18; STRADNER, 1959b, p. 479, fig. 42; MARTINI, 1960, p. 79, pl. 9, fig. 20; NOËL, 1960, p. 212, pl. 1, fig. 15; BRAMLETTE and SULLIVAN, 1961, p. 158, pl. 11, fig. 1; MARTINI, 1961, p. 12, pl. 3, fig. 25; NARASIMHAN, 1961, p. 92, pl. 9, fig. 5; STRADNER *in* STRADNER and PAPP, 1961, p. 66, pl. 4, figs. 1–7; pl. 5, figs. 1–6; text-fig. 8–4; BOUCHÉ, 1962, p. 9, pl. 3, fig. 9; *non* text-fig. 27; STRADNER, 1962, p. 181, pl. 1, figs. 1–6; SULLIVAN, 1964, p. 189, pl. 11, fig. 5; LEVIN and JOERGER, 1967, p. 172, pl. 3, fig. 18; PERCH-NIELSEN, 1967, p. 30, pl. 7, figs. 5–9; LOCKER, 1968, p. 223, pl. 1, fig. 14; RADOMSKI, 1968, p. 579; BYSTRICKÁ, 1969, p. 208, pl. 63, figs. 6–8; HOFFMANN, 1970, p. 13, pl. 2, figs. 4–7; GARTNER, 1971, fig. 3; HAQ, 1971a, p. 36, pl. 14, fig. 4; HAQ, 1971b, p. 90, pl. 12, fig. 9; MARTINI, 1971, p. 743, pl. 2, fig. 4.

Remarks: Discoaster with six to nine rays around a large central disc. The central disc bears a flat button. The rays are equal to or longer than the radius of the central disc. Each ray bears a pair of rounded nodes at its half length. The rays are of uniform width to the paired nodes. Beyond the nodes the rays narrow and become rounded at their tips.

Hypotypes: Fort Bend County 6, 9490 (04.1; 76.4), W.U.M.C. 000247; Size: 11 microns. Sabine River E, SEM negative 6483; Size: 13 microns.

Occurrence: Reported from the Paleocene through the Miocene in various parts of the world.

DISCOASTER BINODOSUS HIRUNDINUS
Martini, 1958
Plate 9, fig. 6
Plate 10, fig. 7

Discoaster binodosus hirundinus MARTINI, 1958, p. 362, pl. 4, fig. 19; MARTINI, 1960, p. 79, pl. 9, fig. 21; HAY, MOHLER and WADE, 1966, p. 395, pl. 13, fig. 2; PERCH-NIELSEN, 1967, p. 30, pl. 7, figs. 1–4; HOFFMANN, 1970, p. 15, pl. 2, figs. 2, 3; PERCH-NIELSEN, 1971a, p. 951, fig. 10; PERCH-NIELSEN, 1971b, p. 62, pl. 52, fig. 7.

Discoaster binodosus Martini. BOUCHÉ, 1962, p. 90; text-fig. 27; BYSTRICKÁ, 1964, p. 213, pl. 5, fig. 5; MARTINI, 1971c, p. 743.

Discoaster tani nodifer Bramlette and Riedel. LEVIN, 1965, p. 270, pl. 43, fig. 5; CLOCCHIATTI, 1971, p. 90, pl. 38, fig. 2.

Remarks: Discoasters with six to nine rays about a large central disc. The central disc bears a star-shaped central button. The rays extend beyond the central disc a distance equal to or greater than the radius of the central disc. Each ray bears a pair of nodes at its half length. Beyond the nodes the rays narrow and terminate peripherally with blunt ends which are notched.

The peripheral notch in each ray distinguishes this sub-species from *Discoaster binodosus binodosus.* The specimen illustrated in the light micrograph has thicker rays than is typical of the Weches specimens of this species.

Hypotypes: Polk County 9, 5333 (27.8; 80.2), W.U.M.C. 000248; Size: 15 microns. Sabine River E, SEM negative 6473; Size: 13 microns.

Occurrence: Reported from the upper Eocene and lower Oligocene in Europe.

DISCOASTER DEFLANDREI
Bramlette and Riedel, 1954
Plate 9, fig. 9

Discoaster deflandrei BRAMLETTE and RIEDEL, 1954, p. 399, pl. 39, fig. 6; text-fig. 1a–c; BRAMLETTE, 1957, p. 249, pl. 6, fig. 6; MARTINI, 1958, p. 363, pl. 5, fig. 23; STRADNER, 1959, p. 1087, fig. 25; NOËL, 1960, p. 219, pl. 3, figs. 7–9; BRAMLETTE and SULLIVAN, 1961, p. 158, pl. 11, fig. 4; MANIVIT, 1961, p. 367, pl. 9, fig. 4; MARTINI, 1961, p. 13, pl. 3, fig. 27; STRADNER *in* STRADNER and PAPP, 1961, p. 71, pl. 10, figs. 1–6; text-fig. 8–7; STRADNER, 1962, p. 181, pl. 39, fig.6; SULLIVAN, 1964, p. 190, pl. 11, fig. 8; COHEN, 1965a, p. 23, pl. 7, fig. h; BRAMLETTE and WILCOXON, 1967, p. 109, pl. 7, fig. 4; HAY *et al.,* 1967, p. 460, pl. 2, figs. 6–9; LEVIN and JOERGER, 1967, p. 172, pl. 4, figs. 1, 2; BYSTRICKÁ, 1969a, p. 210, pl. 63, figs. 1–3; RADOMSKI, 1968, p. 579, pl. 47, fig. 6; BYSTRICKÁ, 1969b, p. 83, pl. 13, figs. 1–4; CLOCCHIATTI, 1971, p. 80, pl. 33, fig. 3; pl. 34, fig. 1, 2; GARTNER, 1971, fig. 5., HAQ, 1971b, p. 90, pl. 12, fig. 10; HAQ, 1971c, p. 119. PERCH-NIELSEN, 1971a, p. 951, fig. 10; ROTH, BAUMANN, and BERTOLINO, 1971, fig. 5.

Remarks: Stellate asterolith usually having six rays around a central disc. The rays may be longer or shorter than the radius of the central disc. The more delicate forms in the Weches usually have arms longer than the radius of the central disc while the more robust forms have arms shorter than the central disc. The distal one-half to one-third of the rays thicken and bifurcate, producing a gently tapering wide open V-shaped terminal notch. The terminal notch may be rounded but is usually angular. The outline of the thickened area is angular or rounded. The area between rays is subcircular. The central disc sometimes bears a distinct knob.

Hypotype: Fort Bend County 6, 10180 (15.8; 75.4), W.U.M.C. 000249; Size: 12.5 microns.

Occurrence: Reported from the Paleocene to the lower Miocene in various parts of the world.

DISCOASTER DIASTYPUS
Bramlette and Sullivan, 1961
Plate 9, fig. 13

Discoaster diastypus BRAMLETTE and SULLIVAN, 1961, p. 159, pl. 11, figs. 6–8; SULLIVAN, 1964, p. 190, pl. 10, figs. 3, 4;

SULLIVAN, 1965, p. 41; GARTNER, 1971, figs. 1, 3, 5; MARTINI, 1971c, p. 743; PERCH-NIELSEN, 1971a, p. 951, fig. 8; PERCH-NIELSEN, 1971b, p. 62, pl. 51, fig. 8–10.

Discoaster aff. *D. diastypus* BRAMLETTE and SULLIVAN, 1961, pl. 11, figs. 9, 10.

Remarks: Asteroliths with nine or ten broad, sharply pointed rays joined through most of their length. The nearly straight rays surround a central button on the convex side and a stem on the concave side.

Hypotype: Austin County 5, 9625(29.7; 75.5), W.U.M.C. 000250; Size: 10 microns.

Occurrence: Reported from the lower Eocene in the United States and Europe.

DISCOASTER DISTINCTUS
Martini, 1958
Plate 11, figs. 6–8
Plate 12, figs. 3, 5

Discoaster distinctus MARTINI, 1958, p. 363, pl. 4, fig. 17; MARTINI, 1959, p. 138; STRADNER, 1959, p. 1086, *non* fig. 20; STRADNER, 1959 p. 484, *non* figs. 33–39; MARTINI, 1960, p. 77, pl. 9, fig. 15; BRAMLETTE and SULLIVAN, 1961, p. 159, pl. 11, figs. 11–13; MARTINI, 1961, p. 14, pl. 3, fig. 28; NARASIMHAN, 1961, p. 83, pl. 9, fig. 14; pl. 1, fig. 6; STRADNER *in* STRADNER and PAPP, 1961, p. 72, pl. 2, fig. 1; BOUCHÉ, 1962, p. 91, pl. 3, fig. 14; text-fig. 30; STRADNER, 1962, p. 181, pl. 2, fig. 1; SULLIVAN, 1964, p. 190, pl. 11, fig. 7; SULLIVAN, 1965, p. 41, pl. 10, fig. 4; HAY, MOHLER and WADE, 1966, p. 395, pl. 13, *non* fig. 2; BUKRY and KENNEDY, 1969, fig. 3, no. 6; BYSTRICKÁ, 1969, p. 210, pl. 63, figs. 10, 11; HODSON and WEST, 1970, p. 167, pl. 1, fig. 1; MARTINI, 1971c, p. 743; PERCH-NIELSEN, 1971a, p. 951, fig. 10; PERCH-NIELSEN, 1971b, p. 63, pl. 52, fig. 5; pl. 53, fig. 1.

Remarks: Discoasters with five or six rays. The rays are appreciably longer than the radius of the central disc. The central disc bears a distinct star-shaped button. The sides of the rays are sub-parallel, thinning as they leave the central disc. At one-half to three-fourths the length of the ray a strong bifurcation and rapid lateral thickening occurs, producing a deep rectangular shaped terminal notch in each ray. Close to or at the point of bifurcation a pair of lateral nodes often occurs on the sides of the rays.

TEM micrographs by Hodson and West (1970) have revealed that the deep terminal notches are partly filled by calcite and thus appear less pronounced in electron micrographs. SEM micrographs of specimens from the Weches Formation also show the notch to be filled.

Hypotypes: Hurricane Shoals M (19.6; 76.1), W.U.M.C. 000251; Size: 11 microns. Smithville A, SEM negative 5882; Size: 10.5 microns. Fort Bend County 6, 9490, SEM negative 5794.

Occurrence: Reported from the middle and upper Eocene in various parts of the world and the lower Eocene of France.

DISCOASTER ELEGANS
Bramlette and Sullivan, 1961
Plate 10, figs. 2, 4
Plate 11, figs. 1, 2

Discoaster elegans BRAMLETTE and SULLIVAN, 1961, p. 159, pl. 11, fig. 16; STRADNER *in* STRADNER and PAPP, 1961, p. 97, pl. 28, figs. 4a, b; BOUCHÉ, 1962, p. 89, pl. 3, figs. 5–7; text-figs. 18–20 and c; SULLIVAN, 1964, p. 190, pl. 10, figs. 1, 2; RADOMSKI, 1968, p. 580; BYSTRICKÁ, 1969a, p. 211, pl. 40, figs. 7–10; PERCH-NIELSEN, 1971a, p. 951, fig. 8; PERCH-NIELSEN, 1971b, p. 63, pl. 51, figs. 2, 3.

Discoaster stradneri NOËL, 1960, p. 215, pl. 2, *non* fig. 7; MARTINI, 1961, p. 10, pl. 2, fig. 22; pl. 5, fig. 52.

Discoaster barbadiensis Tan. NARASIMHAN, 1961, p. 73, pl. 9, fig. 18; HAY and TOWE, 1962, p. 515, pl. 10, figs. 3, 5; CLOCCHIATTI, 1971, p. 72, pl. 30, figs. 1–4; RAMSAY, 1971, p. 206, pl. 1, fig. 4.

Discoaster boulangeri LEZAUD, 1968, p. 23, pl. 1, figs. 9–12; pl. 2, fig. 14; PERCH-NIELSEN, 1971b, p. 62, pl. 52, fig. 1.

Discoaster saipanensis Bramlette and Riedel. CLOCCHIATTI, 1971, p. 87, pl. 31, figs. 1–3; pl. 32, fig. 3; text-fig. 18; PERCH-NIELSEN, 1971b, p. 65, pl. 52, fig. 4.

Remarks: Concavo-convex asterolith with 11–15 rays. The rays are arched along their midline and terminate in pointed or blunt tips. SEM micrographs show that the edges of the rays are slightly thickened with a ridge on the concave side of the asterolith. The ridges extend up into a conical stem on the concave side. A small round button is located at the center of the convex side. In the light microscope concentric rings or ridges are observed on both the concave and convex sides of this species. SEM micrographs show these ridges only on the concave side.

The degree of taper to the terminations of the rays is variable. Forms with blunt tips have rays with cross sections that are not gently

Discoaster spp. BRAMLETTE and SULLIVAN, 1961, p. 163, pl. 13, figs. 1–5.

Remarks: Planar asterolith of eight to ten rays. The ray length is less than the radius of the large central disc. The width of the rays is quite variable; some forms have spaces between rays large enough to accommodate an additional ray whereas others have spaces equal to less than half the ray width. The wider the ray the shorter its length relative to the central disc. The sides of the rays are parallel for any given specimen. Slight thickening occurs at the distal end of the rays just before they bifurcate. The terminal notch produced by the bifurcation may be V or U-shaped. At about half the length of the ray, lateral rectangular to rounded projections occur. In the more robust forms the distance between the lateral projections and the terminal thickenings is less.

The central disc bears a star of six to eight points. Teardrop-shaped ridges radiate from just beyond the edge of the star. The large end of the teardrops project slightly beyond the periphery of the central disc into the interray area. The surface of the central disc and the rays are covered with pustules.

The photomicrograph and SEM micrograph (Plate 12, figure 1) are of the same specimen. The photomicrograph shows the teardrop ridges to be prominent and located on the surface of the specimen. The SEM picture shows that no ridges exist on the top surface; it appears that they are located on the underside.

Hypotype: Sabine River E, SEM negative 6469, Size: 18 microns.

Occurrence: Reported from the Eocene in various parts of the world.

PLATE 10

Magnification 4500 X
unless otherwise specified.

Figures — Page

1 *Discoaster barbadiensis* Tan 59
From Fort Bend County 6, 9490, SEM negative 5792.

2, 4 *Discoaster elegans* Bramlette and Sullivan 61
From Smithville A
2. Concave side, SEM negative 4879
4. Convex side, SEM negative 5801

3 *Discoaster tumescens* Noël 68
From Smithville A, SEM negative 5875.

5 *Discoaster mirus* Deflandre 64
2000 X, the same specimen as in Plate 9, Figure 15. SEM negative 6469, from Sabine River E.

6 *Discoaster binodosus binodosus* Martini 59
2200 X, from Sabine River E, SEM negative 6483.

7 *Discoaster binodosus hirundinus* Martini 60
From Sabine River E, SEM negative 6473.

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PLATE 10

rounded but have a wide flat surface on the convex side of the ray. *D. elegans* is distinguished from *D. barbadiensis* by being more strongly convex, having more gently tapered terminations to the rays, showing more relief in Canada balsam, and having a longer stem.

Hypotypes: Smithville A (23.0; 71.2), W.U.M.C. 000252; Size: 15 microns. SEM negative 4879; Size: 14 microns.

Occurrence: Reported from the Paleocene and Eocene in various parts of the world.

DISCOASTER LENTICULARIS
Bramlette and Sullivan, 1961
Plate 9, fig. 18

Discoaster lenticularis BRAMLETTE and SULLIVAN, 1961, p. 160, pl. 12, figs. 1, 2; BOUCHÉ, 1962, p. 90, pl. 3, figs. 11–13; text-figs. 22, 23; SULLIVAN, 1964, p. 191, pl. 11, fig. 1; SULLIVAN, 1965, p. 42, pl. 10, fig. 10; HAY and MOHLER, 1967, p. 1539; RADOMSKI, 1968, p. 582, pl. 48, fig. 1; HAQ, 1971a, p. 39, pl. 14, fig. 5; PERCH-NIELSEN, 1971a, p. 951, fig. 8.

Remarks: Discoidal asterolith with 20–26 narrow rays joined throughout most of their length and terminating bluntly. A smooth central button occupies nearly half the diameter of the asterolith. A shallow depression is located at the center of the button.

Hypotype: Fort Bend County 6, 10180 (12.6; 75.4), W.U.M.C. 000253; Size: 7 microns.

Occurrence: Reported from the upper Paleocene through the lower Eocene in various parts of the world.

DISCOASTER LODOENSIS
Bramlette and Riedel, 1954
Plate 9, fig. 10
Plate 12, figs. 1, 2

Discoaster lodoensis BRAMLETTE and RIEDEL, 1954, p. 398, pl. 39, figs. 3a, b; MARTINI, 1958, p. 366, pl. 6, figs. 28a–d; STRADNER, 1959a, p. 478, figs. 14–16, 19, 20; STRADNER, 1959b, p. 1083, fig. 5; MARTINI, 1960, p. 76, pl. 8, fig. 11; BRAMLETTE and SULLIVAN, 1961, p. 161, pl. 12, figs. 4, 5; MANIVIT, 1961, p. 361, pl. 6, figs. 4, 5; NARASIMHAN, 1961, p. 75, pl. 1, fig. 15, pl. 3, figs. 13, 14; pl. 8, figs. 14, 17; STRADNER, 1961, p. 86, figs. 84, 85; STRADNER *in* STRADNER and PAPP, 1961, p. 92, pls. 25, 26; text-figs. 9–3, 24–9; HAY and TOWE, 1962, p. 514, pl. 10, figs. 2, 4, 6; SULLIVAN, 1964, p. 191, pl. 11, fig. 14; BLACK, 1965, fig. 20; COHEN, 1965a, p. 33, pl. 25, fig. 3; SULLIVAN, 1965, p. 42, pl. 10, fig. 14; HAQ, 1967, p. 63, pl. 7, figs. 3, 6, 7; BYSTRICKÁ, 1969a, p. 214, pl. 61, figs. 1–5; RADOMSKI, 1968, p. 582, pl. 47, figs. 10, 12; BILGÜTAY *et al.*, 1969, p. 173, pl. 3, fig. 3; HAQ, 1969, p. 10, pl. 2, figs. 1–4; text-figs. 4E–G; HAQ, 1971a, p. 39; GARTNER, 1971, figs 1, 2, 4, 5; MARTINI, 1971c, p. 741, pl. 2, fig. 2; PERCH-NIELSEN, 1971a, p. 951, fig. 8; PERCH-NIELSEN, 1971b, pl. 52, fig. 2; RAMSAY, 1971, p. 206; pl. 1, figs. 8, 9.

Remarks: Stellate asterolith of five to seven curved rays which taper to a sharp point. The rays are joined for about one-half their length. The gently convex side of the asterolith bears a prominent stem. A ridge runs along one side of each ray and extends into the center where it becomes part of the stem. The ridges run up the side of the stem and terminate as raised nodes around the edge of the stem. In plan view the rays are seen to spiral counterclockwise on the stem-bearing side. This side of the asterolith has been named the "facies laevagyra" by Stradner.

Light and SEM micrograph 6466 are of the same specimen.

Hypotypes: Sabine River E, SEM negative 6369; Size: 13 microns. SEM negative 6466; Size: 18 microns.

Occurrence: Reported from the lower and middle Eocene in various parts of the world.

DISCOASTER MIRUS
Deflandre, 1952
Plate 9, fig. 15
Plate 10, fig. 5

Discoaster mirus DEFLANDRE *in* GRASSÉ, 1952, p. 465, fig. 362Z, invalid no description; DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 168; text-fig. 118; STRADNER, 1959a, p. 479, fig. 41; NOËL, 1960, p. 217, pl. 2, fig. 10; MARTINI, 1961, p. 12, pl. 3, fig. 24; NARASIMHAN, 1961, *non* p. 89, pl. 1, fig. 17; pl. 9, fig. 7; STRADNER, 1961, p. 1086, fig. 23; STRADNER *in* STRADNER and PAPP, 1961, p. 68, pl. 6, figs. 5, 6; pl. 7, figs. 1–5; text-figs. 8–5, 24–7; BYSTRICKÁ, 1969a, p. 215, pl. 63, figs. 4, 5; BYSTRICKÁ, 1969b, p. 83, pl. 13, figs. 9–11; GARTNER, 1971, fig. 5; PERCH-NIELSEN, 1971a, p. 951, fig. 10; ROTH, BAUMANN, and BARTOLINO, 1971, figs. 5, 7, 9.

DISCOASTER SAIPANENSIS
Bramlette and Riedel, 1954
Plate 9, fig. 16
Plate 12, fig. 4

Discoaster saipanensis BRAMLETTE and RIEDEL, 1954, p. 398, pl. 39, fig. 4; BRAMLETTE, 1957, p. 249, pl. 61, fig. 7; MARTINI, 1958, p. 367, pl. 6, fig. 29; STRADNER, 1959, p. 1083, fig. 3; MARTINI, 1960, p. 76, pl. 8, fig. 12; NOËL, 1960, p. 210, pl. 1, fig. 13; MANIVIT, 1961, p. 359, pl. 6, figs. 1–3; NARASIMHAN, 1961, p. 77, pl. 1, fig. 13; pl. 2, fig. 3; STRADNER *in* STRADNER and PAPP, 1961, p. 90, pl. 22, figs. 6, 7, 9; text-fig. 9–5; HAY, MOHLER and WADE, 1966, p. 396, pl. 11, figs. 8, 9; pl. 13, fig. 1; GARTNER and SMITH, 1967, p. 6, pl. 12, figs. 4, 5; HAQ, 1967, p. 64, pl. 8, figs. 4, 6, 7; HAY *et al.*, 1967, pl. 1, figs. 4–6; LEVIN and JOERGER, 1967, p. 172, pl. 3, fig. 16; RADOMSKI, 1968, p. 584, pl. 48, fig. 2; BILGÜTAY *et al.*, 1969, p. 173, pl. 3, fig. 5; STRADNER, 1969, p. 665, pl. 6, fig. 5; BYSTRICKÁ, 1969a, p. 220, pl. 59, figs. 11–13; BYSTRICKÁ, 1969b, p. 80, pl. 11, figs. 12–17; pl. 12, figs. 1–13; pl. 16, figs. 1, 2; pl. 18, figs. 1, 12; HAQ, 1969a, *non* p. 12, pl. 4, figs. 1–3; text-fig. 2d; CLOCCHIATTI, 1971, p. 87, pl. 31, figs. 1–3; pl. 32, fig. 3; text-fig. 18; GARTNER, 1971, figs. 1, 4, 5; HAQ, 1971a, p. 42; MARTINI, 1971c, p. 741, pl. 2, fig. 20; PERCH-NIELSEN, 1971a, p. 951, fig. 8; PERCH-NIELSEN, 1971b, p. 65, pl. 51, fig. 4; *non* pl. 52, fig. 4; ROTH, BAUMANN, BARTOLINO, 1971, figs. 5–9.

Remarks: Stellate asterolith with six or seven generally straight rays joined through slightly more than one-half their length. Straight to slightly curved ridges radiate from a central knob covering the joined portion of the rays. The free portion of the ray tapers gently, then steeply and terminates in rounded points.

This species is distinguished from *D. barbadiensis* by fewer but more pointed rays and by ridges running along the joined portions of the rays.

Hypotypes: Hardin County 11, 8271 (02.7; 75.4), W.U.M.C. 000254; Size: 13 microns. Fort Bend County 6, 9490, SEM negative 5796; Size: 8 microns.

Occurrence: Reported from the Eocene and lower Oligocene in various parts of the world.

DISCOASTER STELLA
(Ehrenberg)
Gardet, 1955
Plate 11, figs. 3, 4

Discoaster stella (Ehrenberg). GARDET, 1955, p. 529, pl. 8, figs. 81a–e, pl. 11, figs. 98-99; NOËL, 1960, p. 208, pl. 1, figs. 2–11.

Remarks: Stellate asteroliths with six rays. The length of the rays is equal to the radius of the central area. The rays are broad at the margin of the central area but taper to sharp points. The inter-ray area is V-shaped. The rays appear to be inclined at a shallow angle to the surface of the thick central area.

Hypotype: Fort Bend County 6, 10180 (07.4; 71.9), W.U.M.C. 000255; Size: 12 microns.

Occurrence: Reported from the Eocene through the Pliocene in various parts of the world.

DISCOASTER SUBLODOENSIS
Bramlette and Sullivan, 1961
Plate 9, fig. 14

Discoaster sublodoensis BRAMLETTE and SULLIVAN, 1961, p. 162; pl. 12, fig. 6; BOUCHÉ, 1962, p. 90, pl. 3, figs. 18, 19; text-figs. 25, 26; SULLIVAN, 1965, p. 43, pl. 10, fig. 11; GARTNER, 1971, figs. 2, 4; MARTINI, 1971c, p. 741, pl. 2, fig. 3; PERCH-NIELSEN, 1971a, p. 951, fig. 8; RAMSAY, 1971, pl. 1, figs. 8, 9.

Remarks: Stellate asterolith of five or six straight rays. The rays are sharply pointed, widening at first gently and then rapidly as they fuse with the central disc. The length of the rays is greater than the radius of the central disc. A flat circular button is present at the center of the disc.

Hypotype: Fort Bend County 6, 10180 (15.2; 74.9), W.U.M.C. 000256; Size: 13 microns.

Occurrence: Reported from the middle Eocene in various parts of the world.

DISCOASTER TANI NODIFER
Bramlette and Riedel, 1954
Plate 11, fig. 5

Discoaster tani nodifer BRAMLETTE and RIEDEL, 1954, p. 397, pl. 39, fig. 2; MARTINI, 1959, p. 138; MARTINI, 1960, p. 78, pl. 9, fig. 19; NOËL, 1960, p. 218, pl. 2, fig. 13; MANIVIT, 1961, p. 367, pl. 9, fig. 1; NARASIMHAN, 1961, p. 80, pl. 8, fig. 5; LEVIN, 1965, p. 270, pl. 43, fig. 5; HAY *et al.*, 1967, pl. 1, fig. 2; LEVIN and JOERGER, 1967, p. 172, pl. 4, figs. 4–6; HAQ, 1968, p. 46, pl. 10, fig. 7; MARTINI, 1968, p. 240, pl. 1, fig. 5; MARTINI and RITZKOWSKI, 1968, pl. 1, fig. 5; BYSTRICKÁ, 1969, p. 223, pl. 62, fig. 2;

PLATE 11

The long axis of each specimen is parallel to the polarizer unless otherwise specified.

Magnification 1800 X

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1, 2 *Discoaster elegans* Bramlette and Sullivan 61

1. Phase-contrast
2. Hypotype, phase-contrast, from Smithville A (23.0; 71.2), W.U.M.C. 000252.

3, 4 *Discoaster stella* (Ehrenberg) Gardet 65

3. Phase-contrast
4. Hypotype, phase-contrast, from Fort Bend County 6, 10180 (07.4; 71.9), W.U.M.C. 000255.

5 *Discoaster tani nodifer* Bramlette and Riedel 65
Phase-contrast, from Sabine River E (08.6; 79.2), W.U.M.C. 000257.

6–8 *Discoaster distinctus* Martini 61
All figures phase-contrast

7, 8. Illustrate the dominant form in the Weches Formation.
8. Hypotype, from Hurricane Shoals M (19.6; 76.1) W.U.M.C. 000251

9, 10 *Zygrhablithus bijugatus* (Deflandre) Deflandre 71

13, 14

17, 18 9, 10. Hypotype, phase-contrast, between crossed-polarizers, from Smithville A (02.6; 71.6), W.U.M.C. 000263.
13, 14. Hypotype, phase-contrast, between crossed-polarizers, from Fort Bend County 6, 10180 (20.9; 72.3), W.U.M.C. 000264.
17. Phase-contrast
18. Between crossed-polarizers

11 *Discoaster triangularis* Bystricka' 68
Phase-contrast, from Fort Bend County 6, 10180 (06.6; 71.5), W.U.M.C. 000258.

12 *Discoaster woodringi* Bramlette and Riedel 68
Phase-contrast, from Fort Bend County 6, 10180 (14.1; 72.1), W.U.M.C. 000259.

15 *Discoasteroides kuepperi* (Stradner) Bramlette and Sullivan 69
Phase-contrast, concave side, from Sabine River E (11.6; 73.6), W.U.M.C. 000260.

16 *Marthasterites furcatus* (Deflandre) Deflandre 69
Phase-contrast, from Hurricane Shoals J (10.0; 69.9), W.U.M.C. 000261.

19 *Chiphragmalithus calathus* Bramlette and Sullivan 70
Phase-contrast, from Sabine River E (77.7; 73.6) W.U.M.C. 000262.

20 *Neococcolithes dubius* (Deflandre) Black 70
Phase-contrast, from Smithville D_1.

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PLATE 11

STRADNER, 1969, p. 665, pl. 6, fig. 4; ROTH, 1970, p. 868, pl. 12, fig. 4; CLOCCHIATTI, 1971, p. 90, pl. 38, fig. 2; GARTNER, 1971, fig. 1, 4, 5; HAQ, 1971a, p. 42, pl. 10, fig. 13; HAQ, 1971b, p. 91, pl. 12, fig. 4; MARTINI, 1971, p. 743, PERCH-NIELSEN, 1971a, p. 951, fig. 8; ROTH, BAUMANN, and BARTOLINO, 1971, figs. 5, 7, 8.

Discoaster tani Bramlette and Riedel. RADOMSKI, 1968, p. 585.

Remarks: Asterolith of five to seven rays. The rays are robust, of uniform width and bear paired barb-like projections at their half-lengths. This subspecies is distinguished from *D. tani tani* by a terminal notch in each ray. There is a slight widening of the rays adjacent to the terminal notch. The free length of the rays is roughly equal to the radius of the central disc. A star-shaped button is sometimes present at the center of the disc.

Discoaster binodosus hirundinus is distinguished from *D. tani nodifer* by its larger central disc and the central button which is sometimes surrounded by an annular ring. The paired projections along the rays are rounder in *D. b. hirundinus*. The rays narrow from the paired projection to their distal end and bear a more conspicuous terminal notch than *D. t. nodifer*.

Hypotype: Sabine River E (08.6; 79.2), W.U.M.C. 000257; Size: 16 microns.

Occurrence: Reported from the middle and upper Eocene in various parts of the world.

DISCOASTER TRIANGULARIS
Bystrická, 1966
Plate 11, fig. 11
Plate 12, fig. 6

Discoaster triangularis BYSTRICKÁ, 1966, p. 239, figs. 8, 9; BYSTRICKÁ, 1969, p. 223, pl. 64, fig. 11; PERCH-NIELSEN, 1971a, p. 951, fig. 8

Remarks: Triangular-shaped discoaster with six rays. Three long rays alternate with three short rays producing the triangular outline of this species. A large circular button is located at the center of the specimen. The rays are broad, tapering only slightly before terminating in rounded points.

The termination of the rays may be pointed in some specimens. Where the terminations are pointed, the rays are more strongly tapered and shorter in length.

Hypotypes: Fort Bend County 6,10180 (06.6; 71.5), W.U.M.C. 000258; Size: 9 microns across base. SEM negative 6478; Size: 9 microns across base.

Occurrence: Reported from the upper Eocene in the Western Carpathians.

DISCOASTER TUMESCENS
Noël, 1960
Plate 9, fig. 17
Plate 10, fig. 3

Discoaster tumescens NOËL, 1960, p. 207, 218; pl. 3, figs. 1–3; PERCH-NIELSEN, 1971a, p. 951, fig. 9.

Remarks: Stellate aterolith usually with six rays. The free length of the rays is equal to or a little longer than the radius of the central disc. The rays thicken towards the distal end and terminate in subcircular lobes. SEM micrographs reveal the presence of a star-shaped central button with its rays pointing toward the inter-ray areas. The surface of the asterolith is covered with pustules. The inter-ray areas are variable in shape; most are subcircular but some are triangular.

Hypotype: Smithville A, SEM negative 5875; Size: 14 microns.

Occurrence: Reported from the Oligocene to the Miocene in various parts of the world.

DISCOASTER WOODRINGI
Bramlette and Riedel, 1954
Plate 11, fig. 12

Discoaster woodringi BRAMLETTE and RIEDEL, 1954, p. 400, pl. 39, fig. 8; BRAMLETTE, 1957, p. 249, pl. 61, fig. 5; FURRAZOLA-BERMUDEZ and ITURRALDE-VINENT, 1967, p. 9, pl. 1, figs. 4, 5; ROTH, 1970, p. 868, pl. 12, fig. 6; CLOCCHIATTI, 1971, p. 94, pl. 28, fig. 1; GARTNER, 1971, fig. 5; PERCH-NIELSEN, 1971a, p. 951, fig. 8.

Remarks: Rotund asteroliths with six thick rays. The free length of the rays is a little greater than the radius of the central disc. The rays are wide and broadly rounded at their distal end. The inter-ray area is V-shaped or gently rounded.

Hypotype: Fort Bend County 6, 10180 (14.1; 72.1), W.U.M.C. 000259; Size: 11 microns.

Occurrence: Reported from the upper Eocene into the upper Oligocene in various parts of the world.

Genus DISCOASTEROIDES
Bramlette and Sullivan, 1961

Description: Asteroliths having a large, terminally concave stem flaring out as radiate elements at the end. The stem shows an interference pattern in cross-polarized light.

Type Species: *Discoasteroides kuepperi* (Stradner) Bramlette and Sullivan.

DISCOASTEROIDES KUEPPERI
(Stradner)
Bramlette and Sullivan, 1961
Plate 11, fig. 15
Plate 12, figs. 8, 9

Discoaster kuepperi STRADNER, 1959, p. 478, figs. 17, 21; MARTINI, 1961, p. 14, pl. 3, fig. 29; STRADNER *in* STRADNER and PAPP, 1961, p. 93, pl. 27, figs. 1–6; text-figs. 9–6, 16; PERCH-NIELSEN, 1971b, p. 64, pl. 51, figs. 6, 7, 9, 11, 12.

Discoasteroides kuepperi (Stradner). BRAMLETTE and SULLIVAN, 1961, p. 163, pl.13,figs. 16–19; HAY and TOWE, 1962, p. 515, pl. 10, *non* fig. 1; SULLIVAN, 1964, p. 192, pl. 12, figs. 1, 2; SULLIVAN, 1965, p. 44, HAQ, 1967, p. 62, pl. 4, figs. 1–6; BYSTRICKA', 1968, p. 224, pl. 60, figs. 9, 10; HAQ, 1968, p. 47, pl. 10, fig. 6; RADOMSKI, 1968, p. 586, pl. 48, figs. 5, 7–9; BYSTRICKA', 1969, p. 85, pl. 16, figs. 2, 3; HAQ, 1969, p. 15, pl. 3, figs. 1–3; HAQ, 1971a, p. 43; MARTINI, 1971c, p. 743; PERCH-NIELSEN, 1971a, p. 951, fig. 8.

Remarks: Stellate asterolith of seven to ten rays bearing a large, flared, terminally concave heliolithid stem on its concave side. The diameter of the flared end of the stem is equal to one-half that of the asterolith. The rays of the asterolith are joined throughout most of their length and terminate in sharp points. Ridges run between each ray and join the stem. The ridges extend up the sides of the stem and terminate as flared elements of the stem. The stem bears a large concave depression. The flared elements of the stem are located between the rays of the asterolith. Concentric ridges cross each ray on the stem-bearing side. The rays thus look very much like the rays on the concave side of *D. elegans.*

Hypotypes: Sabine River E (11.6; 73.6), W.U.M.C. 000260; Size: 6 microns, and SEM negatives 6334 and 6468; Size: 8 microns.

Occurrence: Reported from the Eocene in various parts of the world, with questionable occurrence in the Paleocene.

Genus MARTHASTERITES
Deflandre, 1959

Description: Three-armed asteroliths with curved or straight arms radiating from an undifferentiated center. The arms may be of variable length and terminate simply or fork and bear variously disposed prongs.

Type species: *Marthasterites furcatus* Deflandre.

MARTHASTERITES FURCATUS
(Deflandre)
Deflandre, 1959
Plate 11, fig. 16
Plate 12, fig. 7

Discoaster furcatus DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 168, pl. 13, fig. 14; STRADNER, 1959, p. 1084, fig. 7; STRADNER, 1959, p. 477, fig. 1; MARTINI, 1960, p. 81, pl. 10, fig. 33.

Marthasterites furcatus (Deflandre). DEFLANDRE, 1959, pp. 133, 138, pl. 2, figs. 3–12, 16; *non* pl. 3, figs. 1–5; DEFLANDRE, 1961, pl. 3, fig. 31; NARASIMHAN, 1961, p. 66, pl. 5, figs. 9, 10, 16; pl. 9, figs. 16, 17; STRADNER, 1961, p. 83, figs. 62, 63; STRADNER *in* STRADNER and PAPP, 1961, p. 108, pl. 34, figs. 1, 2, 5; text-figs. 11–1, 11–3; STRADNER, 1963, pl. 2, fig. 11; STRADNER, 1964, fig. 46.

Trochoasterites hohnensis (Martini). BOUCHE, 1962, p. 91, pl. 4, figs. 13, 14.

Marthasterites hohnensis (Martini). PERCH-NIELSEN, 1971a, p. 951, fig. 9.

Remarks: Tri-radiate asterolith with rays all in the same plane. Each ray appears to be made up of three rectangular elements. The elements are fastened together in such a way as to give a nine-sided cross-section to each ray. The elements are widest at the center of the asterolith but taper gently toward the distal ends of the rays. Here each element curves away from the axis of the ray producing three nodes. Each node may itself bifurcate. Stefan Gartner, Jr., questioned the identification of this specimen in his review of the manuscript.

Hypotypes: Hurricane Shoals J (10.0; 69.9) W.U.M.C. 000261; Size: length of one ray, 4-5 microns. SEM negative 6443; Size: length of one ray, 4-5 microns.

Occurrence: Reported from the Middle Cretaceous to the middle Miocene.

Family ZYGODISCACEAE
Hay and Mohler, 1967

Description: Coccoliths consisting of an open elliptical ring made up of imbricate tabular laths spanned by an I, X, or H-shaped structure which is symmetrical about the short axis of the ellipse. Rim dextrogyre in distal view between crossed polarizers.

Genus CHIPHRAGMALITHUS
Bramlette and Sullivan, 1961

Description: Basket-shaped coccoliths divided into quadrants by cross-septa. The septa may be higher than the side walls.

Type Species: *Chiphragmalithus calathus* Bramlette and Sullivan.

CHIPHRAGMALITHUS CALATHUS
Bramlette and Sullivan, 1961
Plate 11, fig. 19

Chiphragmalithus calathus BRAMLETTE and SULLIVAN, 1961, p. 156, pl. 10, figs. 7, 8–10; SULLIVAN, 1964, p. 179, pl. 1, figs. 3–6; SULLIVAN, 1965, p. 30, pl. 1, figs. 9–18; REINHARDT, 1967, p. 218, pl. 4, fig. 18; PERCH-NIELSEN, 1971a, p. 967, fig. 21; PERCH-NIELSEN, 1971b, p. 47, pl. 39, fig. 4.

Remarks: In side view this species has a rectangular outline, being higher than it is wide. Three irregular ridges are seen to extend the length of the specimen in this view. One end is a little wider than the other. These ridges really are the side walls and one cross septum of the specimen. In plan view the specimens are nearly square with a thin rim surrounding an open central area which is spanned by an X-shaped central structure. The entire specimen is bright in side view between crossed-polarizers.

Hypotype: Sabine River E (77.7; 73.6), W.U.M.C. 000262; Size: 5 x 6 microns.

Occurrence: Reported from the Paleocene and lower Eocene in California and Denmark.

Genus NEOCOCCOLITHES
Sujkowski, 1931

Description: Thin delicate elliptical rim spanned by an H-shaped structure. The rim widens distally; in cross-polarized light the rim appears nearly isotropic.

Type Species: *Neococcolithes lososnensis* Sujkowski.

NEOCOCCOLITHES DUBIUS
(Deflandre)
Black, 1967
Plate 8, figs. 6, 7
Plate 11, fig. 20

Zygolithus dubius DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 149, text-fig. 43, 44, 68; GORKA, 1957, p. 267, pl. 1, fig. 6; MARTINI, 1958, p. 369, pl. 1, figs. 1a–c, *non* 1b; MARTINI, 1960, p. 83, pl. 11, fig. 39; BRAMLETTE and SULLIVAN, 1961, p. 343, pl. 1, fi. 4; *non* fig. 3; BOUCHÉ, 1962, p. 82, pl. 1, fig. 5; COHEN, 1965a, p. 26, pl. 4, fig. 5; PERCH-NIELSEN, 1967a, p. 130, pl. 1, fig. 3; PERCH-NIELSEN, 1967b, p. 28, pl. 5, figs. 13, 14; REINHARDT, 1967, p. 218, pl. 4, figs. 14–16; 19, 20; LOCKER, 1968, p. 222, pl. 2, fig. 19; PERCH-NIELSEN, 1968, p. 22, pl. 1, figs. 1–4; BILGÜTAY *et al.*, 1969, p. 174, pl. 2, figs. 4, 5; MARTINI, 1971c, p. 743.

Chiphragmalithus dubius (Deflandre). SULLIVAN, 1964, p. 179, pl.1, fig. 2; SULLIVAN, 1965, p. 30, pl. 1, figs. 1, 2.

Neococcolithes dubius (Deflandre). BLACK, 1967, p. 143; RADOMSKI, 1968, p. 572, pl. 48, fig. 17; HODSON and WEST, 1970, p. 173, pl. 2, fig. 1; PERCH-NIELSEN, 1971a, p. 967, fig. 21; PERCH-NIELSEN, 1971b, figs. 1, 3–5; RAMSAY, 1971, p. 206, pl. 3, fig. 9.

Zygolithus minutus PERCH-NIELSEN, 1967, p. 28, pl. 5, figs. 6, 7; PERCH-NIELSEN, 1971b, p. 47, pl. 42, figs. 1–4.

Remarks: Coccoliths with a thin elliptical rim enclosing an open central area spanned by an H-shaped structure. The elements of the spanning structure extend above the elliptical rim. The crossbar of the H is aligned parallel to the long axis of the ellipse. The thickness of the crossbar elements is about the same as that of the rim. Elements of the rim and crossbar produce a vague interference pattern.

Neococcolithes dubius is distinguished from *N. protenus* by the presence of an H-shaped structure in the central area which extends up to the rim, and a more elongate elliptical form to the rim.

Hypotype: Smithville D_1, SEM negatives 5819 and 5883; Size: 5–8 microns long.

Occurrence: Reported from the Eocene of various places in the world and the Jurassic in North Africa; the Upper Cretaceous in Poland and the Miocene in Hungary.

Family ZYGOSPHAERACEAE Braarud and Gaarder, 1961

Description: Holococcoliths formed of microcrystals; the shape of the holococcoliths is variable.

Genus ZYGRHABLITHUS Deflandre, 1959

Description: Holococcoliths with a subcircular to elliptical basal ring bearing a diagonal cross which extends upward above the ring in the form of four tapering shafts.

Type Species: *Zygrhablithus bijugatus* (Deflandre) Deflandre.

ZYGRHABLITHUS BIJUGATUS (Deflandre) Deflandre, 1959 Plate 11, figs. 9, 10, 13, 14, 17, 18 Plate 12, figs. 10–12

Zygolithus bijugatus DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 148, pl. 11, figs. 20, 21.

Rhabdolithus costatus DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 159, pl. 11, figs. 8–11; text-figs. 41, 42, 77–79.

Rhabdosphaera semiformis BRAMLETTE and SULLIVAN, 1961, p. 147, pl. 5, figs. 8–10.

Zygrhablithus bijugatus (Deflandre). DEFLANDRE, 1959, p. 135; BRAMLETTE and SULLIVAN, 1961, p. 151, pl. 6, figs. 16–18; BOUCHÉ, 1962, p. 84, pl. 1, figs. 9–11; HAY and TOWE, 1962, p. 502, pl. 2, fig. 2; SULLIVAN, 1964, p. 187, pl. 7, figs. 9, 10; COHEN, 1965a, p. 27, pl. 4, figs. n, m; LEVIN, 1965, p. 267, pl. 42, fig. 1; SULLIVAN, 1965, p. 38; GARTNER and SMITH, 1967, p. 5, pl. 8, figs. 1–6; HAQ, 1967, p. 61; LEVIN and JOERGER, 1967, p. 170, pl. 2, fig. 24; pl. 3, figs. 1–4; HAQ, 1968, p. 40; pl. 7, fig. 10; pl. 9, figs. 10, 11; RADOMSKI, 1968, p. 575, pl. 43, figs. 11–13; STRADNER and EDWARDS, 1968, p. 44, pl. 42, 43; GARTNER and BUKRY, 1969, p. 1218, pl. 140, figs. 3–6; pl. 142, figs. 1, 2; HODSON and WEST, 1970, p. 174, pl. 3, fig. 2; HAQ, 1971a, p. 30, pl. 10, fig. 7; HAQ, 1971b, p. 89, pl. 12, fig. 5; pl. 13, figs 11–14; pl. 17, fig. 8; HAQ, 1971c, p. 118, pl. 17, fig. 5; PERCH-NIELSEN, 1971a, p. 945, fig. 3; PERCH-NIELSEN, 1971b, p. 58, pl. 58, fig. 7–9; pl. 59, fig. 10.

Remarks: Zygoliths with an open elliptical basal ring which widens toward the distal side. The ring is crossed by an X-shaped bridge which extends high above its distal surface as four blades. The blades bifurcate, forming four short prongs at the terminal periphery of the blades. The other branch of each bifurcate blade continues on a short distance and terminates in a rounded node (Plate 12, figure 10).

The rounded terminal node and prong on each blade is not always present. In small forms of this species the blades taper from the distal surface of the basal ring to a sharp distal point (Plate 12, figure 11). In some large specimens the blades have an undulating periphery (Plate 12, figure 12).

The various sizes and morphologies of this species suggest the existence of dimorphic holococcoliths on the coccospheres of *Zygrhablithus bijugatus*..

Hypotypes: Smithville A (02.6; 71.6), W.U.M.C. 000263; Size: 9 x 12.5 microns. SEM negative 5618; Size: 5 x 5 microns. SEM negative 5670; Size: 10 x 8 microns. SEM negative 6397; Size: 7 x 9 microns. Fort Bend County 6, 10180 (20.9; 72.3), W.U.M.C. 000264; Size: 6 x 10 microns.

Occurrence: Reported from the Eocene and Oligocene in various parts of the world.

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PLATE 12

Magnification 4500 X
unless otherwise specified.

Figures — Page

1, 2 *Discoaster lodoensis* Bramlette and Riedel 64
From Sabine River E.

1. The same specimen as in Plate 9, Figure 10, 1800 X, SEM negative 6466
2. 1620 X, SEM negative 6339

3, 5 *Discoaster distinctus* Martini 61

3. From Smithville A, SEM negative 5882.
5. From Fort Bend County 6, 9490, SEM negative 5794.

4 *Discoaster saipanensis* Bramlette and Riedel 65
From Fort Bend County 6, 9490, SEM negative 5796.

6 *Discoaster triangularis* Bystricka´ 68
From Fort Bend County 6, 10180, SEM negative 6478.

7 *Marthasterites furcatus* (Deflandre) Deflandre 69
From Hurricane Shoals J, SEM negative 6443.

8, 9 *Discoasteroides kuepperi* (Stradner) Bramlette and Sullivan 69
From Sabine River E.

8. Concave side, SEM negative 6468
9. Concave side, SEM negative 6334

10–12 *Zygrhablithus bijugatus* (Deflandre) Deflandre 71
From Smithville A.

10. SEM negative 5670
11. SEM negative 5618
12. SEM negative 6397

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PLATE 12

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CALCAREOUS NANNOFOSSILS OF THE LOUISIANA CONTINENTAL SHELF: ADDITIONS AND CORRECTIONS

HUBERT C. SKINNER
TULANE UNIVERSITY

In a recent paper (Sachs and Skinner, 1973a), the first occurrence of the placolith *Gephyrocapsa caribbeanica* Boudreaux and Hay on the Louisiana Continental Shelf was used as one of the bases for recognition of the Pliocene-Pleistocene boundary in this area. The base of the early Pleistocene Terrebonne Shale (interpreted as Zone N. 22) lies a short distance below the first observed *Gephyrocapsa caribbeanica* (rare, 1 to 5 specimens per traverse) and the first abundant occurrence of the planktonic foraminifer *Globorotalia truncatulinoides* (d'Orbigny) in the strata beneath the Louisiana Continental Shelf. The last true occurrence of *Discoaster brouweri* Tan Sin Hok as interpreted in this study is just below this interface. Only worn and reworked specimens of this species were observed from younger samples.

It was recorded (Sachs and Skinner, 1973a, p. 120) that very rare occurrences of *Gephyrocapsa caribbeanica* (less than one specimen per ten fields of view) had been reported previously by Martini and Worsley (1970, 1971) and by Hay (1970) from upper Pliocene cores taken on JOIDES legs 7 and 4. Later, Akers and Koeppel published a paper in which several additional occurrences of rare *Gephyrocapsa caribbeanica* were recorded from middle Pliocene strata (1973, p. 80–83). These include: Rice's Pit, Yorktown Formation; Watson's Landing, Darling Slide, and Jackson Bluff Bed 10, Jackson Bluff Formation; and, unnamed beds, Sayula, Vera Cruz, Mexico, TU 1083. These five localities yielded *Discoaster brouweri* in co-occurrence with rare *Gephyrocapsa caribbeanica* and were interpreted as Zone N. 20 (middle Pliocene) based on the calcareous nannoplankton and planktonic foraminifers present in the samples.

This new evidence makes it clear that at this time the first occurrence of *Gephyrocapsa caribbeanica* cannot be used reliably as one of the criteria for recognizing the Pliocene-Pleistocene boundary. The stratigraphic significance of this placolith and other species of calcareous nannofossils rare in their first appearances remains uncertain.

Errata

Sachs and Skinner (1973a, 1973b) cited the genus *Crystallolithus* Gaarder and Markali erroneously as *"Cristallolithus."* This spelling error appears several times and was repeated in the name of the family based on this genus, Family CRYSTALLOLITHACEAE Hay. The writers are indebted to Helen Tappan Loeblich for her kindness in noting these errors and reporting them.

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NOTES ON *CHICOREUS* (MOLLUSCA:GASTROPODA) FROM THE CENOZOIC OF THE WESTERN ATLANTIC REGION, WITH THE DESCRIPTION OF NEW SPECIES

EMILY H. VOKES

TULANE UNIVERSITY

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I. ABSTRACT

Three new species of fossil *Chicoreus* and two new Recent species are described from the western Atlantic region. The fossil species are: *C. elusivus,* from the late lower Miocene Chipola Formation of northwestern Florida; *C. xestos,* from the middle Pliocene Pinecrest beds of southwestern Florida; and *C. prolixus* from the Pleistocene Moín Formation of Costa Rica. The Recent species are *C. mergus* and *C. bullisi.* In addition, a form that occurs in the Recent fauna of the Gulf of Mexico, here identified as *C. dilectus* variety, becomes the first record of the genus in the early Pliocene Agueguexquite Formation of Veracruz, Mexico. The earliest occurrence of *C. brevifrons* is noted in the middle Miocene (?) Encanto Formation of Mexico. *Chicoreus argo* is shown to be a synonym of *C. spectrum,* a Caribbean Recent species.

II. INTRODUCTION

In an earlier monograph of the gastropod genus *Chicoreus* s.s. in the western Atlantic region (Vokes, 1965) it was noted that there are but few species of *Chicoreus* in this area, in contrast to the many species found in the Indo-Pacific. At that time there was a total of 12 known species, both fossil and Recent, in the entire western Atlantic Cenozoic. Since then extensive collecting has

EDITORIAL COMMITTEE FOR THIS PAPER:

HARVEY R. BULLIS, JR., National Fisheries Service, Miami, Florida.
A. MYRA KEEN, Department of Geology, Stanford University, Stanford, California.
DRUID WILSON, United States Geological Survey, Washington, D.C.

continued in the fossil beds of the area, and much additional collecting of the Recent fauna has been done, primarily by the U.S. Bureau of Commercial Fisheries, under Harvey R. Bullis, Jr., until recently Base Director of the Pascagoula Laboratory. Several new species are among this material and in this paper three fossil and two Recent species of *Chicoreus* are described. However, two of the formerly accepted names, *C. spectrum* (Reeve) and *C. argo* (Clench and Perez Farfante), are herein placed in synonymy, so that the net gain is four. Another fossil species was subsequently removed to *Chicoreus (Phyllonotus)* (Vokes, 1967, p.143). Thus we may now say there are nine fossil and six Recent species, of which two are also represented in the fossil record, or a total of 15 species of *Chicoreus* s.s. in the Cenozoic of the western Atlantic.

In addition to new forms discovered, other new data on occurrences and extensions of both stratigraphical and geographical range are documented. A few errors from the 1965 paper are rectified.

III. ACKNOWLEDGMENTS

The writer wishes to express her gratitude to those persons who contributed material that made this new study possible. They are: J. Wyatt Durham and Joseph H. Peck, Jr., University of California, Berkeley; Harvey R. Bullis, Jr., National Fisheries Service; William G. Lyons, Florida Department of Natural Resources; Mr. and Mrs. Robert C. Hoerle, West Palm Beach, Florida; Mrs. Bonnie McCash, Casey, Illinois; and John Phillips, Santa Barbara, California. She would also like to thank the members of the Editorial Committee for their time and assistance in improving the manuscript.

IV. SYSTEMATIC DESCRIPTIONS

CHICOREUS (CHICOREUS) ELUSIVUS

E. H. Vokes, n. sp.

Plate 1, figs. 1–4

Chicoreus (Chicoreus) cornurectus (Guppy). E. H. VOKES, 1965, Tulane Stud. Geol., v. 3, no. 4, p. 186 (in part, Chipola references only).

Diagnosis: Protoconch small, of 3½ smooth, conical whorls ending at a small varix, with spiral and axial ornamentation immediately well-developed. Probably eight post-nuclear whorls in a full-grown adult, seven maximum in type material. Spiral ornamentation beginnings on first post-nuclear whorl with three smooth cords, continuing to third whorl where smaller spiral threads are intercalated, one between each two major cords; on fourth whorl another set of tertiary threadlets appearing until by fifth and succeeding whorls the entire surface of the shell is covered with spiral lines of varying sizes, superimposed on spiral ridges developed from the original three spiral cords. On the body whorl five or six of these ridges, plus an additional two on the extended siphonal canal. Axial ornamentation on first post-nuclear whorl of about 12 axial lines, forming sharp nodes where they cross the spiral cords; continuing to about the third whorl where every third axial line is strengthened to form a small varix, leaving the others as intervarical nodes, two between each varical pair. By the fourth and succeeding whorls three well-developed varices present on each whorl; where the spiral ridges cross the varices long, open, foliated spines produced, with smaller spinelets where the smaller threadlets cross. On the median whorls two or three spines per varix, and on the body-whorl five or six, corresponding to the major spiral ridges, plus another two on the siphonal canal. Two varical spines at the shoulder with the posterior one the larger, then two median smaller spines, one often almost lost, and finally the two anterior-most spines nearly as large as the second shoulder spine. Two long spines on the siphonal canal, in addition to the long, recurved distal end of each succeeding canal, which gives rise to a strongly diverging spur. Aperture oval; outer lip crenulated into the open spines of the terminal varix, with several paired lirations on the inner side. Inner lip smooth, with a narrow, free-standing rim that crosses over the entrance of the siphonal canal, almost closing it. Canal covered by a thin plate extending from the columellar wall but open by a narrow slit along the varical side.

Dimensions of holotype: height 44.6 mm, diameter (excluding spines) 21.0 mm.

Holotype: USNM 647110.

Type locality: TU 547, west bank of Chipola River, about 2000 feet above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun County, Florida.

Paratype A: USNM 647111; height 29 mm, diameter (excluding spines) 14.5 mm; locality TU 825.

Paratype B: USNM 647112; height 34.5 mm, diameter 19.0 mm; locality TU 655.

Paratype C: USNM 647113 (a fragment to show potential size); height 26.9 mm, width 43.5 mm; locality TU 950.

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimens: Fig. 1, USNM 647110 (holotype). Fig. 2, USNM 647111 (paratype A).

Fig. 3, USNM 647112 (paratype B). Fig. 4, USNM 647113 (paratype C). Other occurrences: TU locality nos. 70, 196, 458, 459, 546, 555, 709, 817, 820, 830, 951, 998.

Discussion: During the more than 15 years that the writer and associates have been collecting fossils from the Chipola Formation of northwestern Florida, numerous fragments of a new, markedly distinct, species of *Chicoreus* have appeared. Prior to the recent finding of the holotype by Mrs. Bonnie McCash the collections consisted of 31 juvenile or broken adults specimens and 117 identifiable fragments. The next best shells previously taken were the one figured as paratype A, from TU 825, and the somewhat atypical paratype B, from TU 655. In addition, there was one complete adult from TU 546, which has, however, a very elongate siphonal canal much like that of *C. spectrum* (Reeve). The name of this species, an arbitrary combination of letters with the connotation of being elusive, was originally bestowed upon the form during the long search for a well-preserved type specimen.

When the writer treated *Chicoreus* s.s. in 1965, she had in her possession only the paratype B and three tiny juvenile specimens from localities TU 70 and 196. Unfortunately the TU 655 specimen is not a normal example of the form or the writer would never have confused it with *C. cornurectus* (Guppy) as she did (1965,p.187).

This new species more nearly resembles the Recent *Chicoreus brevifrons* (Lamarck) than any other species, including *C. cornurectus.* From *C. brevifrons* it differs primarily in the varical spine arrangement: in *C. brevifrons* there are a pair of shoulder spines, which are much like those of *C. elusivus.* However, they are separated by a spinelet not seen in the latter; in *C. brevifrons* these are followed by three approximately equal-sized anterior spines, all smaller than the shoulder spine. *C. cornurecus* has a single shoulder spine and four smaller anterior spines.

Although there is the one elongate specimen from TU 546, mentioned above, in general the species is not as elongate as *C. spectrum.* It also differs from this Recent species in the varical fronds: *C. spectrum* has a single large spine at the shoulder, with three smaller spines anteriorly; *C. elusivus* has one long spine at the shoulder also, but the second spine, immediately anterior to that one is almost as large as the first, then there are two smaller spines, and the two anteriormost spines are almost as large as the shoulder spine.

C. elusivus is smaller than either of these Recent species but it is larger than any other Chipola *Chicoreus.* The fragment here figured as paratype C suggests a total height of at least twice that of the holotype, or some 90 mm. The largest specimens of *C. lepidotus* (Vokes, 1963) or *C. dujardinoides* (Vokes, 1963), the other Chipola species of *Chicoreus,* are both under 60 mm. *C. cornurectus* alone is of a comparable size, with the lectotype being 89.2 mm. The shell is relatively thin, much like some of the Indo-Pacific species. Presumably it is this thinness that causes the shells of larger specimens to be broken too easily to be preserved, leaving only juveniles and fragments as representatives in the fossil record.

From the occurrence list it can be seen that the species was widespread in the Chipola Formation; however, only at TU 546 and 830 does it approach anything but extreme rarity. At TU 546 there have been ten more-or-less entire specimens and 43 fragments. For all other localities, except for the holotype, there are one or two fragments or juvenile specimens. This species is so distinctive that even the smallest piece of a varix, bearing long spines, is readily recognizable.

In addition to the Florida occurences of this new species, in the collections of the Museum of Paleonotology, University of California, Berkley, there is a single specimen from "San Gregorio Rancho, Chiapas." This locality is stated to be lower Miocene in age and there is no question but that it is directly correlative with the Chipola Formation. Along with the specimen of *C. elusivus* there is a specimen of *Poirieria (Panamurex) laccapoia* (Gardner, 1947), another Chipola species. The precise location of this remarkable occurrence is not certain

but it probably is in the lower Grijalva River area.

CHICOREUS (CHICOREUS) BREVIFRONS
(Lamarck)

Plate 1, figs. 5, 6

Figured specimens: Fig. 5, UCMP A-8124; height 40.0 mm, diameter (incomplete) 21.5 mm; locality TU 635, (?) Encanto Formation, Oaxaca, Mexico; middle Miocene. Fig. 6, USNM 734373; height 54.0 mm, diameter (excluding spines) 25.2 mm; Puerto Rico, Recent.

Discussion: In the literature over the last 100 years both *"Murex" cornurectus* Guppy, 1876, and *"Murex" brevifrons* Lamarck, 1822, have been reported from many Caribbean fossil localities. Since 1965 some new material has been recovered and certain additions and deletions should be made to the synonymy of both of these species.

In the collections of the Museum of Paleontology, University of California, Berkeley, there is a specimen of true *C. brevifrons,* from the Isthmus of Tehuantepec, Mexico, upon which the identification made by Woodring (*in* Durham *et al.*, 1955, p. 984) was made. That reference, unfortunately, was overlooked in 1965, for this proves to be the oldest known occurrence of the species. The locality (=TU 635) has been determined by Akers (1972, p. 11), on the basis of planktonic foraminifera, to be middle Miocene in age and is tentatively referred to the Encanto Formation. The Mexican specimen of *C. brevifrons* is here figured for the first time (pl. 1, fig. 5), together with a Recent example of *C. brevifrons* of about the same size (pl. 1, fig. 6) for comparison.

One reference for *"Murex (Chicoreus) calcitrapa* Lamarck" should be deleted from the synonymy of *C. brevifrons.* This is the shell listed by Gabb (1881, p. 350) from the "Pliocene Clay Beds" near Moín, Costa Rica. Collections made at that locality have shown this species to be, not *C. brevifrons,* but a new species here described as *C. prolixus.*

CHICOREUS (CHICOREUS) CORNURECTUS
(Guppy)

As shown above, specimens from the Chipola Formation of northwestern Florida, formerly identified as *C. cornurectus* (Vokes, 1965, p. 187), are referable to the new species herein named *C. elusivus.* It may well be that *C. elusivus* is the direct ancestor of *C. brevifrons,* which subsequently replaced *C. cornurectus* in the more southern reaches of

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PLATE 1

Figures Page

1-4. *Chicoreus (Chicoreus) elusivus* E.H. Vokes, n. sp. (X 1½) 82
1. USNM 647110 (holotype); height 44.6 mm, diameter (excluding spines) 21.0 mm.
Locality: TU 547. Chipola Formation, late lower Miocene.
2. USNM 647111 (paratype A); height 28.5 mm, diameter (excluding spines) 15.6 mm.
Locality: TU 825. Chipola Formation, late lower Miocene.
3. USNM 647112 (paratype B); height 34.5 mm, diameter (excluding spines) 19.0 mm.
Locality: TU 655. Chipola Formation, late lower Miocene.
4. USNM 647113 (paratype C); height 26.0 mm, diameter 43.5 mm.
Locality: TU 950. Chipola Formation, late lower Miocene.

5-6. *Chicoreus (Chicoreus) brevifrons* (Lamarck) (X 1½) 84
5. UCMP A-8124; height 40.3 mm, diameter (incomplete) 21.5 mm.
Locality: TU 635. (?) Encanto Formation, middle Miocene.
6. USNM 734373; height 54.0 mm, diameter (excluding spines) 25.2 mm.
Locality: Puerto Rico. Recent.

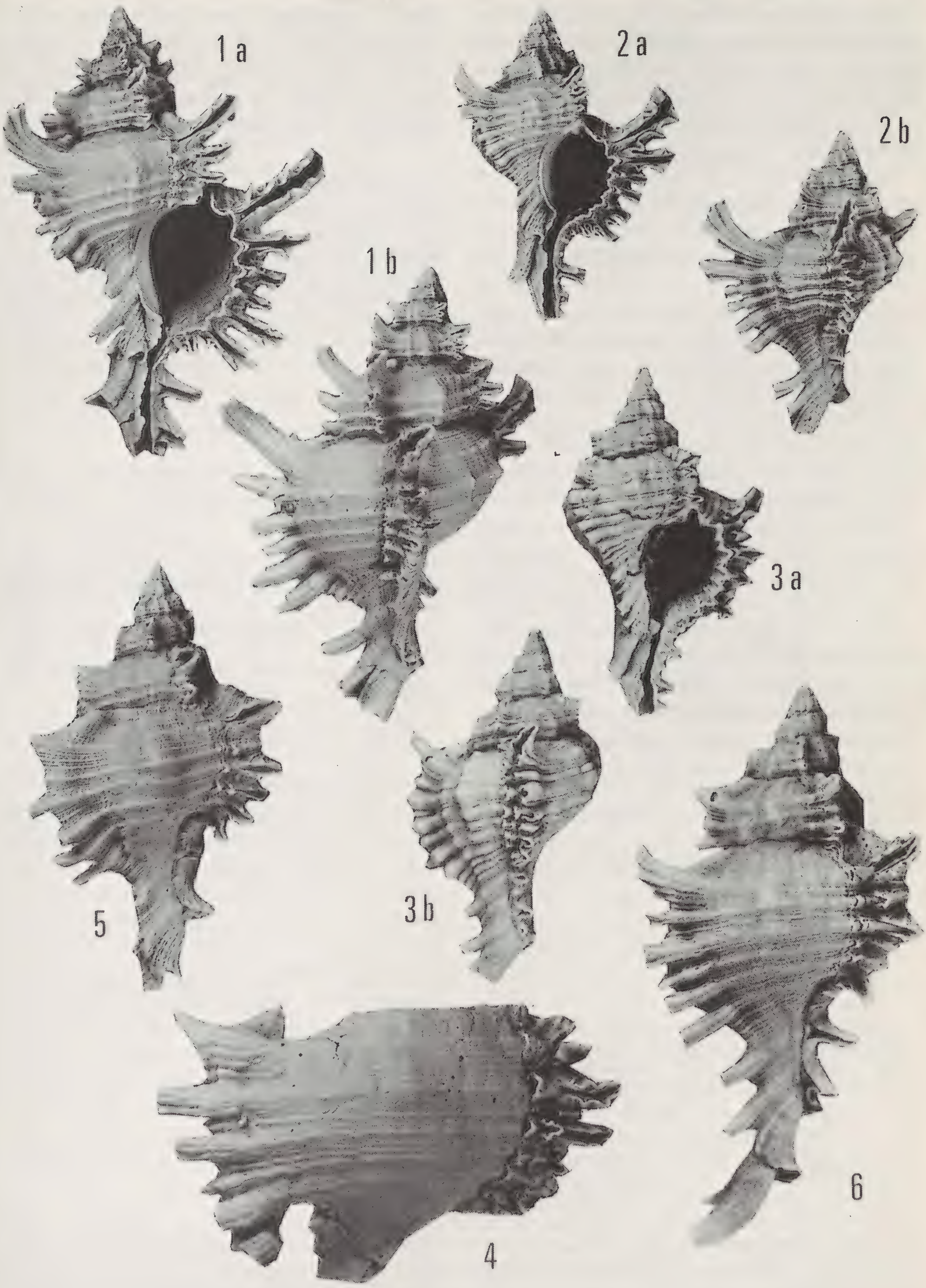

PLATE 1

the Caribbean. Students of planktonic foraminifera are finding, in general, that the beds where *C. cornurectus* occurs, formerly thought to be middle Miocene in age, are upper Miocene.

Jung (1965, p. 521) reported the appearance of two young specimens from the "middle Miocene" Cantaure Formation, of the Paraguana Peninsula, Venezuela, which he felt might be *C. brevifrons.* However, his decision was based upon Woodring's synonymizing of *C. brevifrons* and *C. cornurectus,* for he stated that one of the specimens "agrees perfectly with the figure given by Maury (1917, pl. 16, fig. 10) for *M. cornurectus* Guppy." In the University of California Museum of Paleontology Collection, there is a large specimen of *C. cornurectus* from exactly the same locality as Jung's material (Univ. of Calif. locality no. S–8360, about 300 meters south of Casa Cantaure, which is about 10 km west of Pueblo Nuevo, Paraguana Peninsula). Therefore, it may be assumed that Jung's specimens are also referable to *C. cornurectus.* According to the Second Edition (1970) of the *Lexico Estratigrafico de Venezuela* the Cantaure Formation is now considered upper Miocene in age, and is correlated with the Gatun Formation of Panama and the Cercado and Gurabo formations of Santo Domingo. In all of these beds we find *C. cornurectus.*

CHICOREUS (CHICOREUS) XESTOS

E. H. Vokes, n. sp.

Plate 2, figs. 1, 2

Diagnosis: Protoconch of 1½ whorls, tip noticeably flattened; post-nuclear whorls seven in adult. Spiral ornamentation beginning gradually with three or four small cords, increasing by intercalation to become by the fourth whorl, numerous fine spiral threads, all approximately the same size, with the three or four original cords tending to remain slightly more prominent. On the body whorl, between two of the larger threads about 15 of the finer threads; spiral ornamentation tending to become more subdued on later whorls than on earlier whorls so that the final appearance is one of near smoothness. Axial ornamentation of about 12 small, indistinct nodes on the first post-nuclear whorl, about ten on the second whorl, nine on the third and fourth whorls; by the fifth whorl every third strengthened to form a small varix, with the other two remaining as intervarical nodes; one of the latter becoming increasingly indistinct with each intervarical space, and by about the sixth whorl usually only a single large node present. Three varices on each whorl; ornamented with six equal-sized open foliaceous spines on the body portion, tending to have a thin plate connecting them into a single flange; additional two or three spines on the siphonal canal. Suture deeply impressed causing the whorls to appear very inflated. Aperture oval, anal notch small, open, outer lip crenulated by the varical spines but not opening into them; a series of small paired lirations on the inner side of the outer lip, corresponding to the interspiral areas. Inner lip smooth, with a narrow free-standing callus. Siphonal canal short, open by a narrow slit, recurved at the distal end forming a series of divaricating spurs.

Dimensions of holotype: height 42.3 mm, diameter (excluding spines) 21.7 mm.

Holotype: USNM 647114.

Type locality: TU 1000, Sarasota, Florida, road metal pits at end of 17th Street, about 8 miles east of U.S. Highway 301 (T36S, R19E), Sarasota County, Florida.

Paratype: USNM 647115; height 30.5 mm, diameter (excluding spines) 16.5 mm; locality same as holotype.

Occurrence: Pinecrest beds, Florida; middle Pliocene.

Figured specimens: Fig. 1, USNM 647114 (holotype). Fig. 2, USNM 647115 (paratype).

Discussion: This new species is apparently confined to the Pinecrest beds at Sarasota, Florida; it has not been taken even at nearby localities of approximately equivalent age. The age of the Pinecrest has been previously cited as upper Miocene, but work on the calcareous nannofossils (Akers, this volume, p. 119) has shown the age of the Pinecrest beds to be Zone N. 20, or middle Pliocene.

C. xestos is most nearly akin to *C. floridanus* Vokes, with which it occurs, but has several distinguishing characters. The anal notch is perhaps the single most important difference; that of *C. floridanus,* like that of the younger *C. dilectus* and *C. florifer,* is a narrow, constricted, almost closed tube. The anal notch of *C. xestos* is the more normal *Chicoreus* type, broadly open. The equal-sized varical spines, as opposed to the single larger shoulder spine in all three of the above mentioned species, and the tendency to an interconnecting plate between the spines are other characters that permit the recognition of this new species. But in the

final analysis the most immediately obvious distinction is the smooth appearance of the shell: *C. floridanus, C. dilectus,* and *C. florifer* all are marked by strong spiral cords. It is this feature that gives the species its name *xestos,* a Greek adjective meaning polished or scraped, *i.e.,* smooth.

The aperture of the holotype is not completely formed; hence another example with a complete outer lip is figured as paratype. This smaller specimen also shows the tendency toward the varical flange, which usually is found only in the younger individuals.

CHICOREUS (CHICOREUS) DILECTUS (A. Adams) variety

Plate 2, figs. 3, 4

Figured specimens: Fig. 3, USNM 734374, height 39.0 mm, diameter (excluding spines) 15.5 mm; locality "Hourglass" Station E, 27 degrees 37' N, 84 degrees 13'W, 40 fathoms. Fig. 4, USNM 647116; height (incomplete) 31.5 mm, diameter 24 mm; locality TU 638, Agueguexquite Formation, Veracruz, Mexico; Pliocene.

Discussion: In the Tulane collections from the Isthmus of Tehuantepec area of Mexico over the years there have accumulated a number of fragments (more than 35) of a species of *Chicoreus* taken from two outcrop localities (TU 638, 1046) in the Agueguexquite Formation, of lower Pliocene age (see Akers, 1972, p. 28). These fragments indicate a form that is very closely related to the Recent *C. dilectus* (A. Adams, 1855) but differing in having only five varical spines instead of six. In view of the poor quality of the fossil material there was little that could be done except to record its presence as the only *Chicoreus* known from this formation.

Recently a number of specimens of an unusual form of *Chicoreus,* taken in the Gulf of Mexico by the Florida Department of Natural Resources "Hourglass" Cruises, were sent to the writer for identification. Although they resemble *C. dilectus,* no specimens of *C. dilectus* were taken at the stations where this new form appeared. The specimens are from two "Hourglass" stations, E and M, 75 miles off the west coast of Florida, between Tampa and Fort Myers, at about 40 fathoms. They were sent by Mr. William G. Lyons, who wrote that the form "was quite common at the 40 fathom stations, with as many as six coming up in a single dredge haul."

It is apparent when one compares the Agueguexquite fragments with the "Hourglass" specimens that they are the same morphologic form. Perhaps they represent an ecologic variant for the sole (though consistent) difference from *C. dilectus* is one less varical spine.

Whether this is, in fact, a valid ecologic subspecies remains a question. The depth would not seem to be a factor, for *C. dilectus* has been taken in great numbers not very far away in only slightly shallower water. The answer may lie in bottom type. Mr. Lyons (*in litt.*) writes concerning the "Hourglass" Cruises: "Stations E and M were our two deepest stations (both 73 m); in general, stations at equivalent depths along the two transects were similar, more so than were stations separated by depth along the same transect. A well-defined break occurs between 37 m and 55 m stations along each transect. At 37 m and more inshore, bottoms were of scattered but numerous limestone outcrops, with associated loggerhead sponges, etc. and many "reef" type mollusks. Deeper, there was hardly any rock outcrop, the bottom being smoother; sediments were much finer and more "organic." *Chicoreus dilectus* was most common at 18 and 37 m stations but the "*dilectus* variety" occurred only at 73 m stations." Joyce and Williams (1969, p. 18) describe the stations in greater detail, noting that "operations indicated a generally smooth bottom with a few loggerhead sponges . . . . The bottom is characterized by bryozoans, calcareous algae, foraminifera tests, small sponges, and alcyonarians. The substrate is composed of crushed shell, dead bryozoans, and calcareous algae particles."

It is probable that the Agueguexquite Formation was deposited in an environment not unlike this. In outcrop it is a fine gray silt, with lenses of bryozoan remains and worn, rounded fragments of a colonial coral, which is identified by Dr. John Wells, Cornell University, as *Madracis* aff. *M. mirabilis* (Duchassaing and Michelotti). In these lenses there are many mollusk shells, often tumbled

and worn, and an abundance of foraminiferal tests, both benthonic and planktonic, the most predominant species being *Amphistegina lessonii, Cibicides floridanus, Reussella atlantica,* and *Neoeponides antillarum.* Among the mollusks the most conspicuous members are large turrids of the genera *Scobinella* and *Polystira, P.* cf. *P. tellea* (Dall, 1889) being perhaps the most abundant single species of gastropod in the fauna. These and other relatively deep water forms suggest that turbidity currents may have played a part in mixing a more shallow water fauna with an indigenous deeper one.

CHICOREUS (CHICOREUS) PROLIXUS
E. H. Vokes, n. sp.

Plate 2, fig. 5

Murex (Chicoreus) calcitrapa Lamarck. GABB, 1881, Acad. Nat. Sci. Phila., Jour., (Ser. 2) v. 8, no. 4, p. 350 (*not* of Lamarck).

Diagnosis: Protoconch with large, bulbous whorls, probably two in number, seven post-nuclear whorls in adult. Protoconch ending in a conspicuous band-like varix, with strong ornamentation immediately following. Spiral ornamentation of sharp cords, three in number on first post-nuclear whorl, continuing thus until the fourth whorl where several smaller threads appear; the three strong cords, continuing on succeeding whorls with several smaller threads between each pair; about six major cords on the body-whorl, alternating with a series of smaller threads, which in turn alternate with tertiary threadlets; an additional three major cords and associated smaller spirals on the siphonal canal. Axial ornamentation beginning on first post-nuclear whorl with about 12 indistinct ridges, strengthened by the beginning of the third whorl to form a small varix at every third ridge, three to a complete turn, with the other ridges remaining as two small intervarical nodes between each pair. The varices on each whorl appearing just behind the equivalent varix of the preceeding whorl so that a slightly curving line is formed up the spire. Long, open, foliated spines produced where certain of the major cords cross the varices, that at the shoulder the largest, and two smaller anterior ones, corresponding to the third and fifth cords, abapically from the shoulder; the intervening major cords forming only small open spinelets on the face of the varix. An additional three spines on the extended siphonal canal corresponding to the three major cords there. Suture appressed, situated very low on the whorl so that the spire is noticeably elongated, more so on early whorls than later ones. Aperture ovate to circular, almost entire, but with a small, constricted anal notch adjacent to the suture and a narrow opening into the siphonal canal. Outer lip serrated, corresponding to external spiral ornamentation but not open into the spines; smooth on the inner side. Inner lip also smooth, with narrow free-standing rim. Anterior canal moderately long, slightly recurved at

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PLATE 2

Figures

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1-2. *Chicoreus (Chicoreus) xestos* E.H. Vokes, n. sp. (X 1½) 86
1. USNM 647114 (holotype); height 42.3 mm, diameter (excluding spines) 21.7 mm.
Locality: TU 1000. Pinecrest Beds, middle Pliocene.
2. USNM 647115 (paratype); height 30.5 mm, diameter (excluding spines) 16.5 mm.
Locality: TU 1000. Pinecrest Beds, middle Pliocene.

3-4. *Chicoreus (Chicoreus) dilectus* (A. Adams) variety (X 1½) 87
3. USNM 734374; height 39.0 mm, diameter (excluding spines) 15.5 mm.
Locality: "Hourglass" Station E, 40 fathoms, off west coast of Florida. Recent.
4. USNM 647116; height (incomplete) 31.5 mm, diameter 24.0 mm.
Locality: TU 638. Agueguexquite Formation, Pliocene.

5. *Chicoreus (Chicoreus) prolixus* E.H. Vokes, n. sp. (X 1½) 88
USNM 647117 (holotype); height 49.0 mm, diameter (excluding spines) 23.5 mm.
Locality: TU 954. Moín Formation, early Pleistocene.

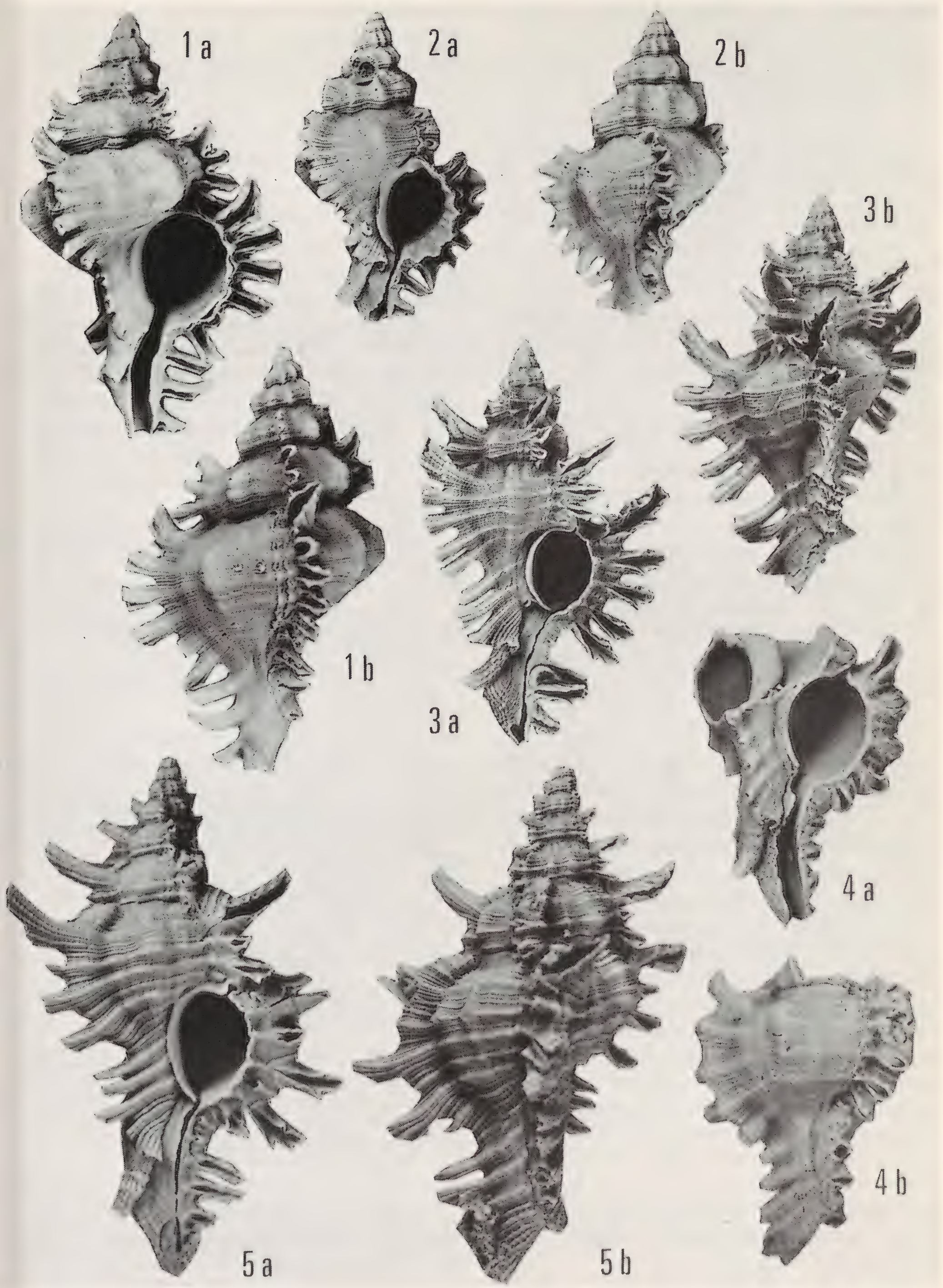

PLATE 2

the distal end, forming a series of spurs that mark the position of former canals.

Dimensions of holotype: height 49.0 mm, diameter (excluding spines) 23.5 mm.

Holotype: USNM 647117.

Type locality: TU 954, hill cut immediately behind Standard Fruit Co. box factory, just west of cemetery at Pueblo Nuevo, about 2 kms west of Puerto Limon, Costa Rica.

Occurrence: Moín Formation, Costa Rica; early Pleistocene.

Figured specimen: USNM 647117 (holotype). Other occurrence: TU locality no. 953.

Discussion: In his list of fossils occurring in the "Pliocene Clay Beds" near Moín, Costa Rica, Gabb cited *"Murex (Chicoreus) calcitrapa* Larmarck." However, collections made both at the type locality of the Moín Formation (TU 953) and nearby in Puerto Limon (TU 954) revealed numerous specimens of a new species of *Chicoreus* but none of *"M. calcitrapa"* (= *C. brevifrons).* As some 10 entire specimens, plus numerous fragments, of the new species were recovered it seems safe to assume that this was, in fact, the form that Gabb had before him.

The resemblances between *C. brevifrons* and *C. prolixus,* n. sp., seem to be little more than generic in nature. The new species is actually much more akin to *C. bullisi,* n. sp., also described herein, than to any other species of *Chicoreus* in the Caribbean region. *C. prolixus* shows the same peculiar constricted anal notch of the Recent *C. florifer, C. dilectus,* and *C. bullisi,* and this alone would be adequate to separate it from *C. brevifrons.* However, the varical spines are completely different from either *C. florifer* or *C. dilectus,* both of them having six varical spines, the shoulder spine being larger and the five anterior spines of approximately the same size. *C. bullisi* has a single large shoulder spine and three smaller anterior spines, but *C. prolixus* has only a single large shoulder spine and two smaller anterior spines. The spire of *C. prolixus* has an unusually elongated appearance for the genus, hence the name *prolixus,* a Latin word meaning "stretched out" (commerated in our English word "prolix").

The age of the Moín beds from both the megafauna and planktonic microfauna is early Pleistocene (Akers, 1972, p. 44); they are correlated with the unnamed post-Caloosahatchee formation of south Florida (see Emerson, 1964, p. 8).

CHICOREUS (CHICOREUS) SPECTRUM (Reeve)

Plate 3, fig. 1

Murex spectrum REEVE, 1846, Conch. Icon., v. 3, *Murex,* pl. 36, fig. 187.

Murex (Chicoreus) imbricatus HIGGINS and MARRAT, 1877, Literary and Philosophic Soc. Liverpool, Proc., v. 31, p. 413, pl. 1, fig. 2. *Non Murex imbricatus* Brocchi, 1814; *nec* Risso, 1826; *nec* Nardo, 1847.

Murex (Chicoreus) argo CLENCH and PÉREZ FARFANTE, 1947, Johnsonia, v. 1, no. 17, p. 31, pl. 17. New name for *Murex imbricatus* Higgins and Marrat.

Murex argo Clench and Pérez Farfante. CLENCH, 1953, Johnsonia, v. 2, no. 32, p. 360, pl. 178 (holotype).

Murex argo Clench and Pérez Farfante, VERRILL, 1959, Nautilus, v. 63, p. 127, pl. 10, fig. 2.

Murex argo Clench and Pérez Farfante. RIOS, 1964, Hawaiian Shell News, v. 13, no. 2, p. 4.

Chicoreus (Chicoreus) argo (Clench and Pérez Farfante). E. H. VOKES, 1965, Tulane Stud. Geol., v. 3, no. 4, p. 194.

Chicoreus (Chicoreus) spectrum (Reeve). E. H. VOKES, 1965, Tulane Stud. Geol., v. 3, no. 4, p. 195.

Murex argo Clench and Pérez Farfante. PLOCKELMAN, 1966, Seafari (Palm Beach Shell Club), v. 8, no. 9, p. 3, four text figures.

Murex spectrum Reeve. PLOCKELMAN, 1966, Seafari (Palm Beach Shell Club), v. 8, no. 11, p. 3, text figure of holotype.

Murex spectrum Reeve. MATTHEWS, 1967, Est. Biol. Mar. Univ. Fed. Ceará, Arq., v. 7, no. 1, p. 102.

Murex (Chicoreus) spectrum Reeve. RIOS, 1970, Coastal Brazilian Seashells, p. 78, pl. 22.

Figured Specimen: Holotype—British Museum (Nat. Hist.) no. 1950-10-23-1; height (incomplete) 113 mm; diameter (excluding spines) 49 mm; locality unknown. Photograph reprinted courtesy of the Trustees of the British Museum.

Discussion: In 1965 there were only a few known specimens referable to either *C. argo* or *C. spectrum;* therefore, there was some reluctance on the part of the writer to place them in synonymy. Since that time numerous specimens have been collected and it now is

evident that the two names *C. spectrum* and *C. argo* refer to the same form. Although the holotype of the former was figured previously in a shell club publication, *Seafari,* it seems appropriate to refigure it here in the interest of greater circulation.

In 1965 the only localities reported (Vokes, 1965, p. 194-195) for both "species" were the Lesser Antilles islands of Granada and Dominica. There had been another record of *"Murex argo"* from off the northeastern coast of Brazil (Rios, 1964, p. 4) but, as the *Hawaiian Shell News* is not usually the place to find occurrence records of western Atlantic species, it was overlooked. Since that time numerous specimens have been taken off the Brazilian coast. Matthews (1967, p. 103) reported examples from off the states of Marahañao and Rio Grande Do Norte. Rios (1970, p. 78) added the states of Piaui and Bahia, and northern Brazil seems to be the general area for most of the specimens that have appeared on the shell market.

CHICOREUS (CHICOREUS) MERGUS
E. H. Vokes, n. sp.

Plate 3, fig. 2

Diagnosis: Protoconch of 1½ large, smooth whorls, ending at a marked varix; seven post-nuclear whorls in the adult. Ornamentation on early whorls consisting of three spiral cords and about a dozen small axial nodes, reduced to three varices and three intervarical nodes on second and all subsequent whorls. Three major spiral cords continue through penultimate whorl and an additional three major cords appear on the body with two or three major cords developed on the extended siphonal canal, for a total of usually nine major spirals on the final whorl. Between these major spirals about six or eight smaller threadlets, alternating in size. One long spine produced where the shoulder spiral crosses each varix and at the junction of three of the remaining five major spirals additional smaller spines are also formed. Tertiary spinelets may appear at either of the other cords but in general the pattern, from posterior to anterior, is large shoulder spine, bare spiral, small spine, very small spinelet, and then two more small spines, corresponding to the six major spirals, with an additional two or three small spines on the anterior canal. Axial ornamentation of three heavy varices and three strong intervarical nodes on each whorl, with numerous fine axial growth lines giving a typical shagreened texture to the entire shell surface. Aperture small, ovate-circular, surrounded by a small, smooth raised rim, nearly entire but with an almost closed anal notch. Outer lip smooth, not folded into the spines of the terminal varix. Color of shell light to dark brown, with darker brown varices and spiral ornamentation. Operculum ovate, corneus, with a somewhat laminar surface, and with a latero-basal nucleus typical of the *Chicoreus florifer* group. Radula also typical of the *Chicoreus* group, small, with three larger cusps and two smaller intermediate cusps on the rachidian tooth, and two simple hook-like lateral teeth.

Dimensions of holotype: height 48.8 mm, diameter (excluding spines) 25.0 mm.

Holotype: USNM 734375.

Type locality: Bridgetown, Barbados, 40 fathoms.

Occurrence: Recent only, from Florida Keys to northern South America. R/V *Oregon* Stations 6435 (dead shell only), 5731, 5732, 5737; also Queenstown, British Guiana, 50 fathoms; Loo Key, Florida (Edith Mugridge, Sanibel, Florida, Coll.); TU locality no. R-287.

Figured specimen: USNM 734375 (holotype).

Discussion: This new species and *C. bullisi,* n. sp. have a strong degree of similarity and, although they are separated geographically for the most part, there is some overlapping of ranges in the southern Caribbean. *C. mergus* is the more widespread species, ranging from the Florida Keys to the Gulf of Darien, occurring in depths of less than 50 fathoms. It is usually confused with the more common *C. florider* (Reeve), which is larger, with more elaborate spines, and with five smaller spinelets on each varix, in contrast to the three of *C. mergus*. From *C. bullisi* it differs in being smaller, darker, and less frondose. The varical pattern, however, in the two species is identical, with a single large shoulder spine and three smaller spines, which are divided into two parts by an almost obsolete spinelet. The two forms may represent only ecologic variants, with *C. mergus* being the shallow water form and *C. bullisi* the deeper water form. But inasmuch as the two ranges are essentially distinct it seems more likely that they represent two divarications from a single parent.

CHICOREUS (CHICOREUS) BULLISI
E. H. Vokes, n. sp.

Plate 3, fig. 3

Diagnosis: Shell large in size, whorls convex, sutures appressed. Protoconch of 1½ smooth

bulbous whorls; termination of nuclear whorls marked by a small varix and the abrupt initiation of ornamentation. Spiral sculpture consisting of primary threads, three on earlier whorls, increasing to six on body-whorl; secondary threads variable, usually two between each pair of primaries; several tertiary threadlets between each pair of secondary threads. Axial sculpture consisting of 12 equal nodes on the first two whorls; certain of these on subsequent whorls being strengthened to form three varices, usually with a single intervarical node between each pair, although a trace of a second intervarical node may sometimes appear; varices offset slightly on succeeding whorls, forming a spiral line up the spire. Spines on each of the varices formed where the major spirals cross; on the body-whorl the shoulder spine by far the largest; proceeding anteriorly the second and fourth spines much reduced, almost lost; third, fifth and sixth somewhat larger. Three larger spines on the extended siphonal canal and one or two additional spinelets in the area between the spines of the body-whorl and those of the canal. Aperture oval, with a small, constricted, almost tubular anal notch, curving into the suture. Outer lip erect and crenulated at the edge by six raised areas where the primary spiral threads terminate; smooth on inner side. Parietal lip smooth, slightly reflected over the body at the posterior end, free-standing at the anterior end. Siphonal canal moderately long, broad and gently recurving over the entire length; former canals divergent. Color from totally white to light brown. Operculum ovate, corneous, with a somewhat laminar surface and latero-basal nucleus typical of the *C. florifer* group. Radula also typical of the *Chicoreus* group, small, with three larger cusps and two smaller intermediate cusps on the rachidian tooth, and two simple hook-like lateral teeth.

Dimensions of holotype: height 65.0 mm; diameter (excluding spines) 31.5 mm.

Holotype: USNM 734215.

Type locality: R/V *Oregon* Station 6456, 13 degrees 54' N, 81 degrees 58' W, about 90 miles off the east coast of Nicaragua, 75 fathoms.

Occurrence: Recent only, off the Caribbean coast of Nicaragua. R/V *Oregon* Stations 3578, 6437, 6456, 6457, 6461.

Figured specimen: USNM 734215 (holotype)

Discussion: This new species is not unlike *C. florifer* (Reeve), which occurs in essentially the same geographic area. It may be distinguished from that form by the different arrangement of varical spines: those of *C. florifer* have five equal-sized smaller spines anterior to that at the shoulder, which is largest; *C. bullisi* having also the large shoulder spine but only three smaller anterior spines. The spines of *C. bullisi* are less flaring and open, and together with the lesser number give an "uncrowded" appearance to the varices. However, the peculiar constricted anal notch of *C. florifer* may be seen in *C. bullisi*, which together with *C. mergus* brings to four the number of Recent species marked by this development.

There seems to be a direct ancestral relationship between *C. prolixus*, n. sp., from the Pleistocene of Costa Rica and *C. bullisi*, the fossil species differing primarily in the possession of a greatly elongated spire and one less small spine on each varix. Both forms have the *C. florifer* type of anal notch and in general are very similar in overall appearance.

PLATE 3

Figures — Page

1. *Chicoreus (Chicoreus) spectrum* (Reeve) (X 1) 90
BMNH no. 1950-10-23-1 (holotype); height (incomplete) 113 mm, diameter (excluding spines) 49 mm.
Locality: Unknown. Recent.

2. *Chicoreus mergus* E.H. Vokes, n. sp. (X 1½) 91
USNM 734375 (holotype); height 48.8 mm, diameter (excluding spines) 25.0 mm.
Locality: Bridgetown, Barbados, 40 fathoms. Recent.

3. *Chicoreus (Chicoreus) bullisi* E.H. Vokes, n. sp. (X 1¼) 91
USNM 734215 (holotype); height 65.0 mm, diameter (excluding spines) 31.5 mm.
Locality: R/V *Oregon* Station 6456, 90 fathoms, off the east coast of Nicaragua. Recent.

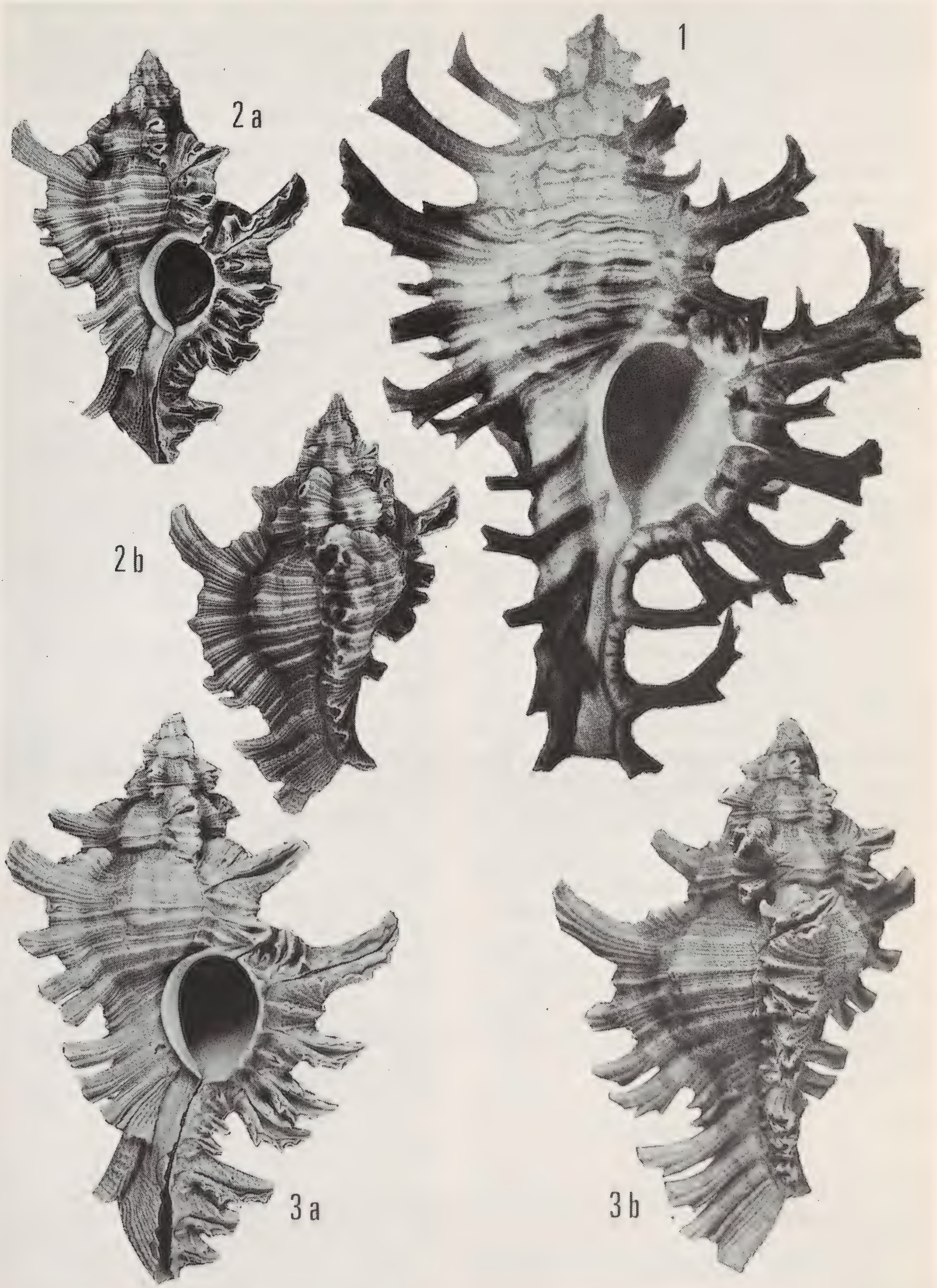

PLATE 3

C. bullisi is a deeper water form than either *C. florifer* or *C. brevifrons* (Lamarck), the other species of *Chicoreus* that occur in the same area. Springer and Bullis (1956, p. 28) report *C. florifer* from 5 to 58 fathoms; Bullis (1964, p. 105) reports *C. brevifrons* from 15 to 40 fathoms; and Bayer (1971, p. 157) adds new data of 6 to 45 fathoms for the latter. *C. bullisi* has been taken only from 75 to 100 fathoms, deeper than is usual for the genus *Chicoreus*.

As noted above, this species has a marked resemblance to *C. mergus*, n. sp. The latter is the smaller of the two, with a maximum size of about 50 mm. The largest specimen of *C. bullisi* seen is a paratype from *Oregon* Station 6457 that measures 85 mm in height. There is also a marked color difference, with *C. mergus* ranging from usually dark brown to rarely light brown, whereas *C. bullisi* is usually pure white, but occasionally a light brown specimen is seen. The relationship between the two forms is much like that between *C. florifer* and *C. dilectus*. *C. bullisi* has a much more restricted range than does *C. mergus*, the latter being found along the outer edge of the Caribbean to the north coast of South America and along the coast to the Gulf of Darien. *C. bullisi* is apparently confined to a small area off the Nicaragua coast. This is probably not an artifact of collecting, for the R/V *Oregon* has made many dredge hauls in all of the Caribbean and northern South American region and the localities cited above are the only ones where this species was taken.

This new species is named for Harvey R. Bullis, Jr., who has made available a tremendous amount of western Atlantic molluscan material not only to the writer but to the scientific world as a whole.

V. LOCALITY DATA

The following are Tulane University fossil locality numbers:

70. Chipola Fm., Ten Mile Creek, at bridge of Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
196. Chipola Fm., Ten Mile Creek, about ¼ mile upstream from bridge of Florida Highway 73 (NE ¼ Sec. 11, T1N, R10W), Calhoun Co., Florida.
458. Chipola Fm., east bank of Chipola River, above Farley Creek (SW ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
459. Chipola Fm., east bank of Chipola River, steep bank about 1500 feet above the mouth of Taylor Lake Branch (NW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
546. Ten Mile Creek, about 1¾ miles west of Chipola River (NW ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
547. Chipola Fm., west bank of Chipola River, about 2000 feet above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
555. Chipola Fm., east bank of Chipola River, about 1000 feet above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
635. Encanto Fm. (?), roadcut on Mexico Highway 185, 1.4 miles south of bridge over Rio Jaltepec, Oaxaca, Mexico.
638. Agueguexquite Fm., roadcut and quarry on Mexico Highway 180, 14 miles east of junction of side road into Coatzacoalcos, Veracruz, Mexico.
655. Chipola Fm., Ten Mile Creek, about 0.1 mile downstream from bridge of Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
709. Chipola Fm., Ten Mile Creek, about ¼ mile downstream from bridge of Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
817. Chipola Fm., south side of Ten Mile Creek, large gully on property of Mr. A. Sexon (1967) (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
820. Chipola Fm., Farley Creek, at bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
825. Chipola Fm., Farley Creek, at abandoned mill about ¼ mile west of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
830. Chipola Fm., Ten Mile Creek, at power line crossing about one mile west of Chipola River (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
950. Chipola Fm., Chipola River, west bank about 2000 feet above Farley Creek (SW ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
951. Chipola Fm., Ten Mile Creek, about 1¼ miles west of Chipola River (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
953. Moín Fm., (type locality) Moín Hill, railroad cut and adjacent ditches on road to Sandoval, 4.5 km west of Puerto Limon, Costa Rica.
954. Moín Fm., Hill cut immediately behind Standard Fruit Co. box factory, just west of cemetery at Pueblo Nuevo, about 2 km west of Puerto Limon, Costa Rica.

998. Chipola Fm., Ten Mile Creek, about 1¼ miles west of Chipola River (SW ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
1000. Pinecrest Beds, Sarasota, road metal pits at end of 17th Street, about 8 miles east of U.S. Highway 301 (R36S, R19E), Sarasota Co., Florida.
1046. Agueguexquite Fm., road cut on Mexico Highway 180, 7.5 miles east of junction with side road into Coatzacoalcos, Veracruz, Mexico.

The following is a Tulane University Recent locality number.

R-287. Corn Island, about 50 miles east of Bluefields, Nicaragua.

The following are National Marine Fisheries Service (formerly U.S. Bureau of Commercial Fisheries) R/V *Oregon* dredging localities.

	Latitude North	Longitude West	Depth in fathoms
3578.	12°28'	82°25'	100
5731.	8°45'	77°26'	43
5732.	8°46'	77°27'	44
5737.	9°37'	79°03'	36
6435.	12°37.5'	82°20'	83
6437.	12°34'	82°23'	80/85
6456.	13°47.5'	81°57'	90
6457.	13°54.5'	81°58'	75
6461.	14°10'	81°57.5'	80

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NOTES ON THE FAUNA OF THE CHIPOLA FORMATION – XV

ON THE OCCURRENCE OF *"RANELLA" POPPELACKI* HORNES, A GASTROPOD OF UNCERTAIN AFFINITIES

EMILY H. VOKES
TULANE UNIVERSITY

Although the affinities of the Chipola Formation with the European Miocene beds of the Aquitaine Basin have been noted previously (Vokes, 1965), the similarities of the fauna to that of the Vienna Basin are less obvious. There is a certain degree of likeness, as both have numerous tropical genera in common, with species of *Mitra, Cypraea, Cassis,* and such, that have an air of familiarity about them. But the differences in the fauna are more conspicuous and there are numerous genera that are totally lacking in the Chipola but present to a greater or lesser degree in the Vienna Basin. One of these would be *Tibia,* certainly a tropical genus, that occurs in the Vienna fauna but not in the Chipola. Even more noticeable are the Mediterranean elements such as *Ocenebra, Ocinebrina, Aporrhais, Argobuccinum,* etc., that have no equivalent in the Chipola fauna. Therefore, it is of special interest to discover a species, which occurs in both faunas, that is not only similar but probably identical.

The specimen here illustrated (text fig. 1) is the sole example known from the Chipola Formation (at TU 951) and, as a comparison with the Hörnes illustration also given (text fig. 2) will demonstrate, there seems to be no discernable difference between the Chipola shell and the one from the Vienna Basin. This small species (both are about 12 mm) was named *Ranella poppelacki* by Hörnes (1853, p. 215) and was said by him to be very rare at Steinabrunn.

The beds at Steinabrunn, which is about 50 miles north of Vienna, are almost certainly Tortonian in age, and the similarity of the species in the Chipola and at Steinabrunn are best attributable to facies. According to Hörnes (1856, map. p. 712) the locality is in the "Lethyakalk" facies, of which Gignoux (1955, p. 569) says: The Tortonian, well developed in the intra-Alpine Basin, is represented by two principal facies . . . The second is the facies of the Leitha limestone *(Leithakalk),* developed around the Leitha Massif, which formed an island surrounded by rocky depths, and which is therefore an organic facies with *Lithothamnium,* bryozoans, large ornate pelecypods (spondyles, pectens) and reef echinoids." Obviously a marl much like that found in the Chipola, it is not surprising that *Typhis wenzelidesi,* the only other Vienna Basin species that has a very near Chipola equivalent in *Pterotyphis vokesae* Gertman, also comes from Steinabrunn.

The generic assignment of *"Ranella" poppelacki* is a genuine puzzle. Although described as *Ranella,* it obviously does not belong in this group for the differences between it and the members of the Bursidae (Ranellidae of authors) are immediately obvious. The two characters that they do have in common consist of the pronounced anal notch and a tendency toward two varices on opposite sides of the aperture. However, the bursids, or "Frog Shells," as the name implies are typified by a "warty" surface ornamentation; the varices are neatly aligned up the spire, and the siphonal canal is much shorter.

The species has also been referred to the genus *Eupleura* by Glibert (1952, p. 309) in a discussion of a French species that bears a slight similarity to our little enigma. The French species, *"Ranella" alata* Millet, differs from *"R." poppelacki* in having a very slight anal sinus and in having a strongly cancellate surface ornamentation. However, neither is referable to *Eupleura,* a genus that is apparently confined to the New World, and is characterized by thickened rather than thin flange-like varices and a calcitic shell. No known species of *Eupleura* has an anal notch.

"Ranella" alata Millet, from the middle Miocene of the Aquitaine Basin, and another French species, *"Argobuccinum" boutillieri* Cossmann, from the Lutetian of the Paris

Basin, are much alike, both having a strongly cancellate surface ornamentation, two opposite varices, and only the slightest of anal notches. These two species have proved to be a problem to French workers equal to our "*Ranella,*" in that the generic assignments for the two over the years have included: *Ranella, Triton, Colubraria, Argobuccinum, Eutritonium,* and *Eupleura.* This is virtually a catalogue of all genera with two varices. They obviously fit in none of these but just where they do fit has been a mystery.

The general tendency has been to place these two-varixed species into either the Bursidae or the Cymatiidae. The writer, for a time, also considered the possibility of the Muricidae. Although the vast majority of the Muricidae do have at least three varices, there is one genus of Typhinae (*Distichotyphis* Keen and Campbell, 1964) that has but two varices. The nature of the aperture in these "*Ranella*" species is much like that of the Muricinae, with a thick, wing-like varix and a completely separate lip formed in advance. Indeed, except for the irregularly placed varices there is a strong resemblance between "*R.*" *poppelacki* and the species assigned to the subgenus *Pterynotus* (*Pterochelus*). However, there is one very critical difference between this enigmatical form and all of the members of *Pterynotus* and this is the nature of the early whorls. As the writer has noted previously (*e.g.*, Vokes, 1968, p. 86), the members of the genera *Pterynotus* and *Poirieria*, two of the most ancient muricine lines, are marked by having on the first post-nuclear whorl six small flange-like varices. In *Poirieria* these simply continue to the adult stage, but in *Pterynotus* on about the second post-nuclear whorl every other varix is lost, or greatly weakened, and a shell with three varices and three intervarical nodes per whorl develops. In "*R.*" *poppelacki* on the first post-nuclear whorl there are a dozen raised, cord-like ribs, equal in strength from suture to suture. They bear absolutely no resemblance to the early varices of *Pterynotus.* On the second post-nuclear whorl certain of the ribs form small open varices, but these are random in arrangement with from two to five intervarical nodes between each pair. This pattern continues up to the adult stage.

The search for a genus, or even family, for this species led to the Australian species originally described as *Daphnellopsis murex* Hedley, 1922.* The type, a tiny 5 mm specimen, has a very marked resemblance to "*R.*" *poppelacki*, differing only in that the Recent form has even fewer varices, just two on the body whorl, and one on the penultimate whorl, none prior to that. But this is clearly a juvenile specimen with only three post-nuclear whorls. At the same stage of development "*R.*" *poppelacki* would have an almost identical appearance.

The Australian species *Daphnellopsis murex* is unquestionably congeneric with our Chipola shell. The only differences seen between the two forms are the stronger intervarical nodes of the older species, and a more rounded aperture. However, whether the two are referable to the genus *Daphnellopsis* seems very doubtful. *Daphnellopsis* was described in the *Siboga* Reports (Schepman, 1913) on the basis of five small specimens (all dead) of a new species taken at 247 meters in the Suva Sea, off the Lesser Sunda Islands, Indonesia. The type species, *Daphnellopsis lamellosa,* has strong cancellate ornamentation and possesses but a single terminal varix unlike the other species under discussion. The two specimens originally figured by Schepman (1913, pl. 30, fig. 10a, b, c) are about the same size, 9 mm (one lacks the protoconch and is smaller), and have four post-nuclear whorls, so it cannot be certain whether this is the adult stage or not.

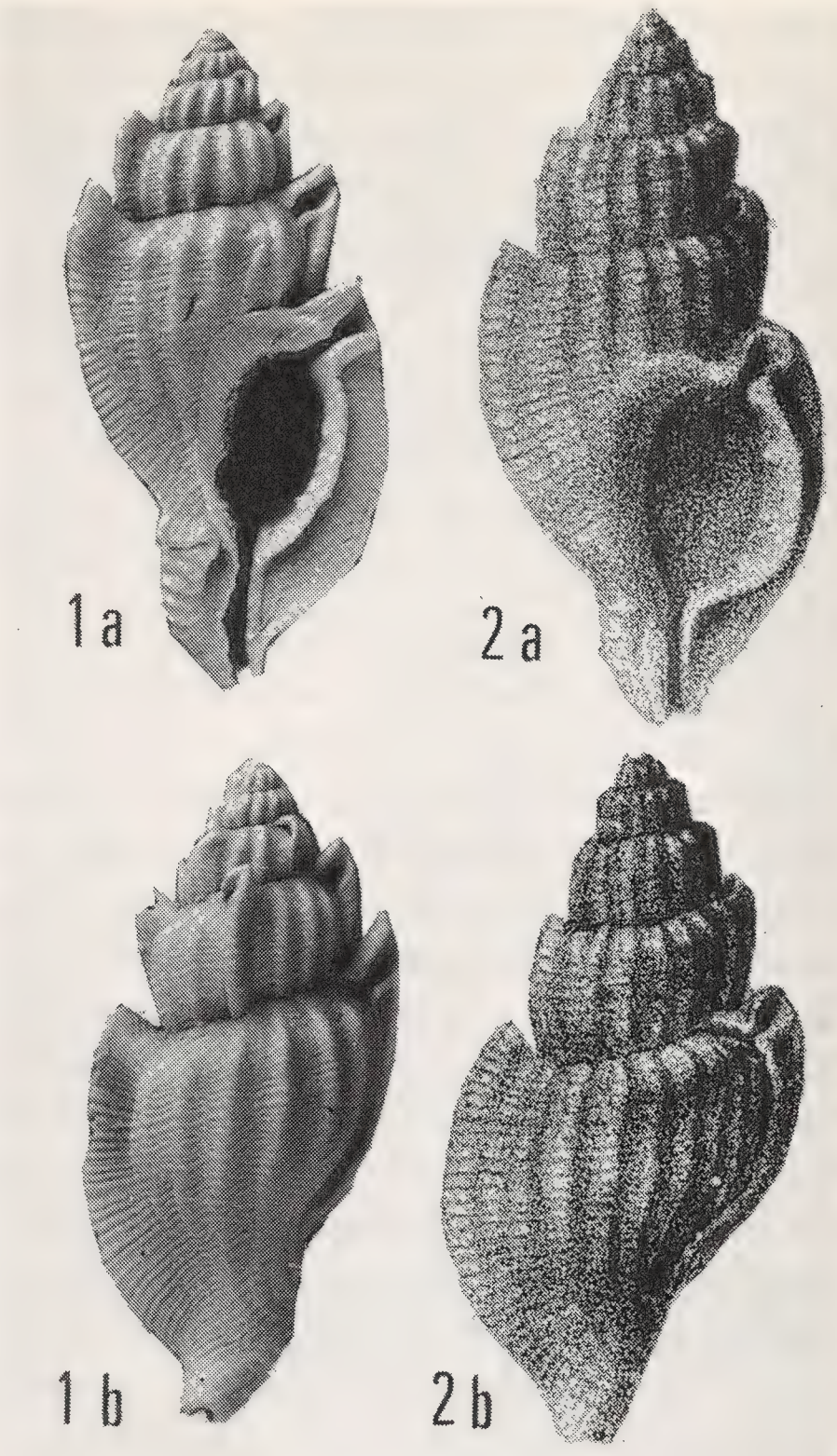
Iredale (1918, p. 33) has rejected *Daphnellopsis* as a turrid, stating that "from the figure, Schepman's *Daphnellopsis* is a close relation to the groups Dall separates as *Macutotriton*, etc., the canal in this case being the one seen in the *Bursa* family, and not of turrid significance." But to this writer the illustration certainly shows an inbending of the axial ornamentation that is consistent with the Turridae, and the nature of the elongate aperture seems closer to the turrids than to either the Australian or the Chipola species. The appearance of only a terminal varix on *D. lamellosa,* as opposed to

*The writer recently referred this species to *Pterochelus* (Vokes, 1971, Bulls. Amer. Paleont., v. 61, no. 168, p. 73). For reasons now obvious this was a mistake.

the repeated varices of the other forms, also suggests that the similarities are mere coincidence for the writer knows of no turrids that form multiple varices. Certainly the size of *D. lamellosa* is such that if multiple varices were going to appear they would already be present; the type of "*D.*" *murex* with one less whorl than *D. lamellosa* already shows three such varices.

Thus, it is probable that *Daphnellopsis* is indeed a turrid, as its rather deepwater habitat would corroborate, but the depth of the Australian form strongly contraindicates this placement, as it was taken in 5 to 8 fathoms, on the Great Barrier Reef (Murray Island). It seems certain that neither the Australian species nor the Chipola one are to be referred to the Turridae, for there is no suggestion of an inbending of the growth lines anterior to the suture, as would be the case in the Turridae.

Thus, instead of finding a genus in which to place "*Ranella*" *poppelacki*, all we have succeeded in doing is finding another species that should be placed in the same unknown genus. The two French species "*Ranella*" *alata* and "*Argobuccinum*" *boutillieri*, are only distantly related to "*R.*" *poppelacki* and "*D.*" *murex*, but seem more closely related to them than to any other group. It would seem probable that we have representatives of two genera of the same family, all of which are unnamed. With no more material than is presently available, the writer has no intention of erecting any new taxa but only wishes to call attention to the extreme similarity of these three isolated specimens, one from the Miocene of Germany, one from the Miocene of Florida and one from the Recent of Australia. Here is simply another unexplained item in the continuing problem of trans-oceanic distribution of tropical non-pelagic gastropods.



Text figure 1. "*Ranella*" *poppelacki* Hörnes, USNM 647012; height 11.7 mm, diameter 5.8 mm; locality TU 951, Ten Mile Creek, Calhoun County, Florida. Text figure 2. "*Ranella*" *poppelacki* Hornes, copy of Hörnes, 1856, pl. 21, figs. 12c, 12d; height (*fide* Hornes) 13 mm, diameter 7 mm; locality, Steinabrunn, Austria. (All figures X 4)

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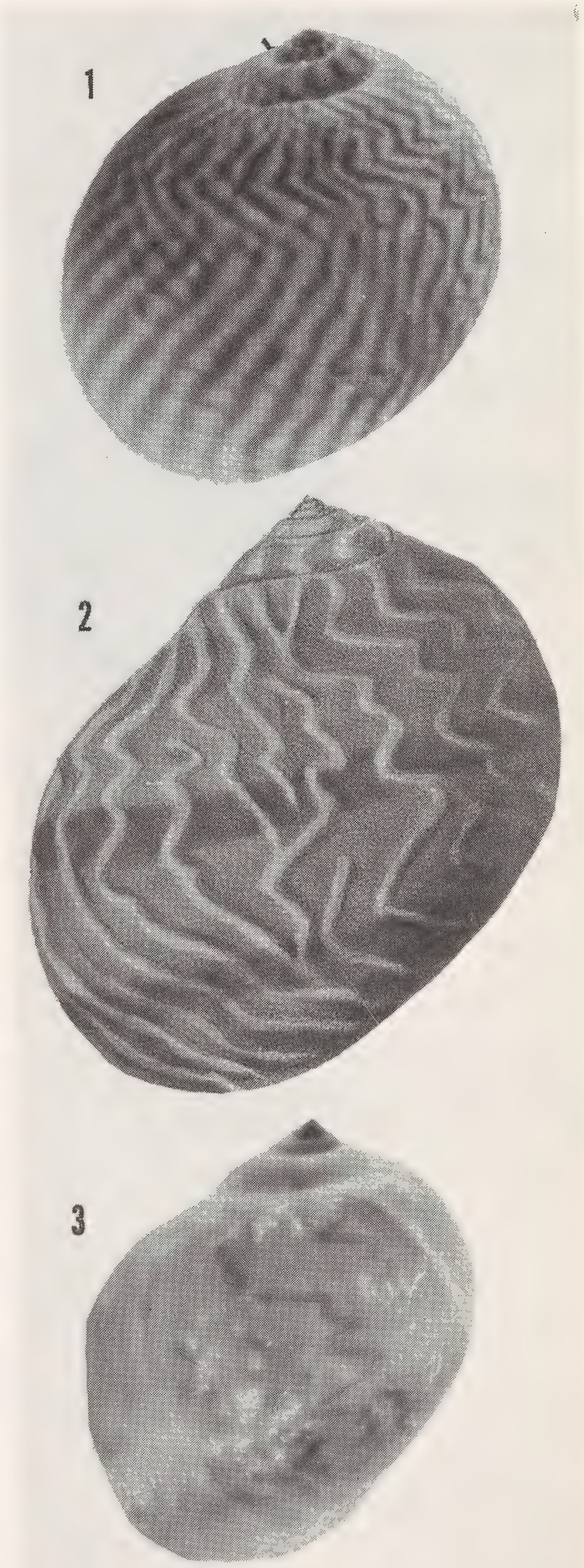
July 31, 1974

NOTES ON THE FAUNA OF THE CHIPOLA FORMATION—XVI
ON THE COLOR PATERN OF *GLOBULARIA FISCHERI* (MOLLUSCA:GASTROPODA)

EMILY H. VOKES
TULANE UNIVERSITY

The large inflated naticoid gastropod named *Ampullina fischeri* by Dall (1892, p. 374) is a moderately common species throughout the Chipola Formation, occuring at almost every Tulane locality on the Chipola River, Ten Mile Creek, and Farley Creek. Such widespread distribution is rare among the Chipola species for more often than not there is a pronounced paleoecological influence apparent in the distribution of a species. This is not the case with *Globularia fischeri,* which seems equally common in the limy facies of the lower parts of the formation (*e.g.*, localities 546 & 830), the sandy "beach-like" parts (459 & 548), the coral-reef facies (458,547,&555) and the silty upper beds of Ten Mile Creek (70 & 655). The greatest number of specimens has been taken at the type locality, "one mile west of Bailey's Ferry" (TU 546=65 specimens), closely followed by TU 458 (60 specimens) and 555 (48 specimens); but a total of 350 examples from 27 localities indicated its relative abundance throughout the formation. Gardner (1947, p. 556) lists the species as questionably occurring at Alum Bluff (USGS 2211) but this is almost certainly in error; no specimens have been taken there by us. In addition to the Chipola occurrences the species also is found rarely in the Oak Grove Sand (TU 91), making its ubiquity almost complete.



Text figure 1. *Globularia fischeri* (Dall); USNM 647318; height 33.5 mm, diameter 33.0; locality TU 459 (color pattern as shown under ultraviolet light); X 1½. Text figure 2. *Globularia fluctuata* (Sowerby); from Reeve, 1855, Conchologia Iconica, *Natica,* pl. 3, fig. 10a; Mindoro, Philippine Islands; X 1. Text figure 3. *Globularia sigaretina* (Lamarck); USNM 643719;height 30.0 mm, diameter 32.0 mm; Paris Basin, Eocene (color pattern as shown under ultraviolet light); X 1½.

The genus *Globularia* has a long geologic history, being represented in the Eocene of the Paris Basin by the species *G. sigaretina* (Lamarck), type of the genus, and in the Recent of the Indo-Pacific by *G. fluctuata* (Sowerby). The principal distinction between the Recent form and the Chipola one is the nature of the color pattern. Investigation with ultraviolet light shows *G. fischeri* to have a pattern similar to *G. fluctuata* but with more numerous zigzag lines. In the Recent form the pattern is a brown ground color with widely spaced light-colored axial zigzags but in *G. fischeri* the dark and light colors are almost equally divided, giving a striped dark and light appearance to the shell. The Eocene ancestor has yet a third variation on this theme, a light ground color, with widely spaced dark zigzags. The three species are figured here for comparison. The two fossil species were photographed under ultraviolet light, which gives a "negative" color pattern, and therefore a second negative was made to restore the original nature of the light and dark portions.

The members of the genus that do not form a callus over the umbilicus, such as *G. sigaretina,* the type species, have been segregated from those that do form such a callus, such as the modern *G. fluctuata,* which has therefore been made the type of a different genus–group, *Cernina* Gray, 1842. *G. fischeri* has no callus and is umbilicate up to a size of about 10 mm, at which time it develops a callus just like that of *G. fluctuata.* In view of the transitional nature of this feature and the marked similarity of the color pattern there seems little justification in keeping the two forms separate even at the subgeneric level.

LOCALITY DATA

The following are Tulane University fossil localities. Except as noted all are in the Chipola Formation, Calhoun County, Florida.

70. Ten Mile Creek, at bridge of Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W).
91. Oak Grove Sand, (type locality), west bank of Yellow River, about 100 yards below bridge at Oak Grove, (NE ¼ Sec. 20, T5N, R23W), Okaloosa Co., Florida.
458. East bank of Chipola River, above Farley Creek (SW ¼ Sec. 20, T1N, R9W).
459. East bank of Chipola River, steep bank about 1500 feet above the mouth of Taylor Lake Branch (NW ¼ Sec. 29, T1N, R9W).
546. Ten Mile Creek, about 1½ miles west of Chipola River (NW ¼ Sec. 12, T1N, R10W).
547. West bank of Chipola River, about 2000 ft. above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W).
548. West bank of Chipola River (NW ¼ Sec. 29, T1N, R9W).
549. East bank of Chipola River, about ¼ mile below Four Mile Creek (NE ¼ Sec. 32, T1N, R9W).
555. East bank of Chipola River, about 1000 ft. above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W).
655. Ten Mile Creek, about 0.1 mile downstream from bridge of Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W).
830. Ten Mile Creek, at power line crossing about one mile west of Chipola River (SE ¼ Sec. 12, T1N, R10W).

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July 31, 1974

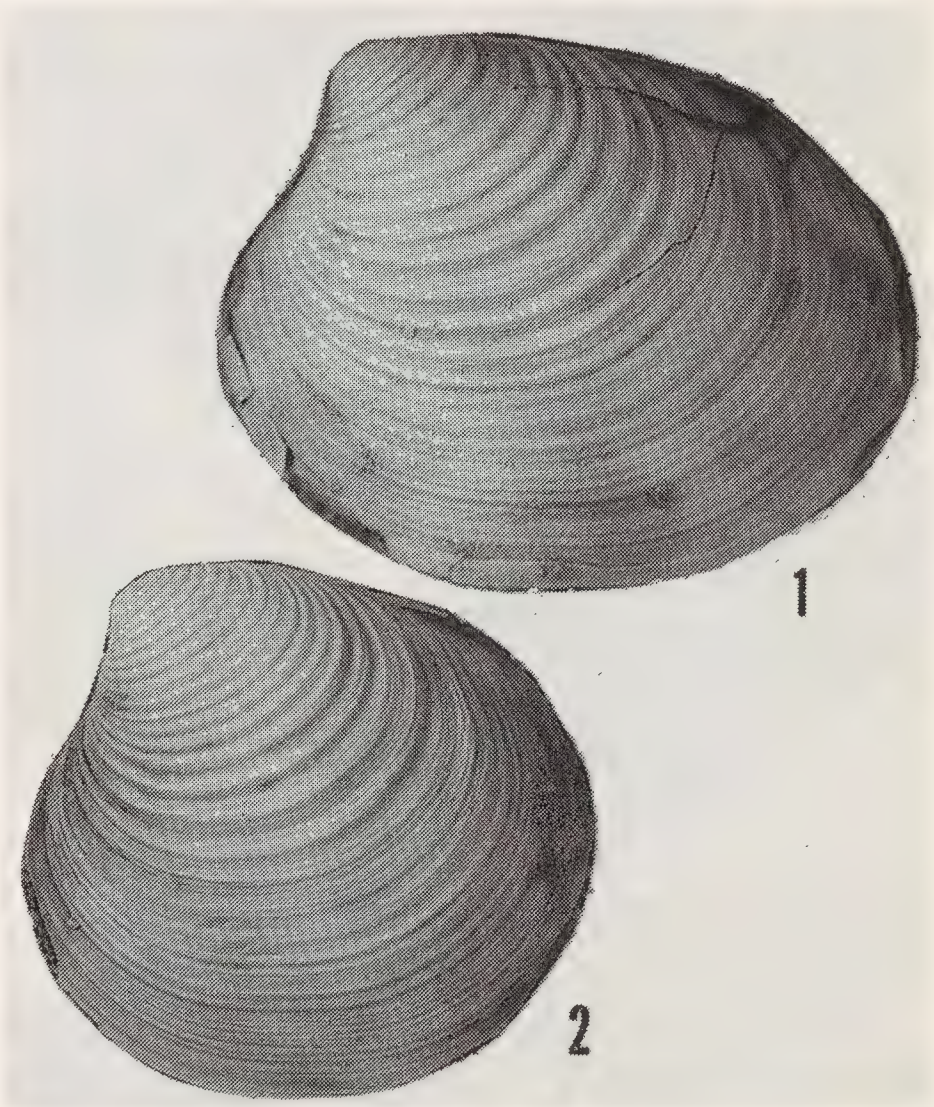
NOTES ON THE FAUNA OF THE CHIPOLA FORMATION – XVII
ON THE PRESENCE OF *CLEMENTIA (EGESTA) GRAYI* DALL

HAROLD E. VOKES
TULANE UNIVERSITY

In 1900 Dall figured *Clementia Grayi* Dall" from the "Oligocene of Oak Grove sands" (1900, pl. 37, fig. 12) and in 1903 (p. 1236) described it briefly but gave no indication as to its relative abundance. In 1926 [Sept. 20] Gardner repeated Dall's description and republished his original illustration (p. 154, pl. 24, fig. 6). Later in 1926 [Nov. 22], Woodring (p. 37, pl. 15, fig. 4) referred Dall's species to the subgenus *Egesta* Conrad, giving a much more complete description and a photograph of the holotype, stating that it is "an almost perfect left value, although the hinge is defective. It is the only fully adult specimen discovered except two broken internal molds. The shell . . . is relatively thick, so thick that the concentric waves are not visible on the interior. It is the only shell that is so thick. The concentric waves are visible on the interior of a piece of shell collected at the same locality, but this thinner shell is smaller than the holotype. All the young shells are thin."

Woodring cited a number of localities, in addition to the type locality in the Oak Grove Sand. The majority of the Chipola occurrences listed are in the outcrops west of the type area in the vicinity of the Choctawhatchee River in Washington and Walton countries. In the region of the type Chipola, however, he noted but one specimen, from USGS Tertiary station 7151, "north bank of Tenmile Creek at wagon bridge on road from Forestville to Marianna, Calhoun County, Fla." This bridge was probably the one whose wooden piers may yet be observed in the stream about one-fourth of a mile west of the present bridge on Florida Highway 73 – the Clarksville/Marianna road.

The principal purpose of this note is to record the fact that *C. grayi* is a moderately common element in the Chipola fauna at



Clementia (Egesta) grayi Dall; locality TU 196 (X 1). Fig. 1, USNM 647437, length 46.7 mm, height 39.8 mm, diameter (paired valves) 23.5 mm. Fig. 2, USNM 647438, length 37.8 mm, height 37.0 mm, diameter (paired valves slightly compressed) 19.5 mm.

exposures along Tenmile Creek. The Tulane University collections contain 33 paired-valve specimens plus 10 right and 7 left valves, which were obtained from almost every locality along the creek except those immediately above the contact with the underlying Chattahoochee Formation. Nine of the paired-valve specimens plus 4 of the right valves were collected from TU 70, which is immediately below the bridge on Florida Highway 73, mentioned above.

A number of these specimens are incomplete because of the fragile nature of the thin-shelled valves, and many more examples encountered when collecting

disintegrated beyond repair either in the field or during laboratory preparation.

In contrast to this relative abundance on Tenmile Creek, it may be noted that our extensive collections from the strata exposed along the Chipola River contain but one paired-valve specimen plus fragments of one right and one left valve; all are from different localities. The difference in relative abundance in these two areas may be a reflection of differences in the nature of the sedimentary matrix present in the two areas. The strata exposed along Tenmile Creek appear to have a much higher clay and silt content than do the beds exposed in the Chipola River banks, where the matrix appears to be primarily a lime-sand material. In accord with these differences it may be noted that the Tenmile Creek sediments tend to be of a blue-gray color, while those of the Chipola River exposures are grayish buff when fresh and weather to a more yellowish tint. A study of the sediments of the type Chipola outcrops, now in progress, may yield more precise data explaining this, and other striking faunal differences.

Examination of these collections reveals that this species exhibits a considerable degree of variation in the shape of the valves. This was commented upon by Gardner (1926, p. 155) in comparing specimens from the Shoal River horizon with the type specimen; the former appearing "to be relatively higher and less elongated transversely. The specimens are, however, too poorly preserved to warrant description." The Tulane Chipola collections contain forms similar to the type (see text fig. 1) associated with the higher and short forms noted by Gardner (text fig. 2) as well as with specimens of intermediate outline. These differences present no valid basis for separation of the second species.

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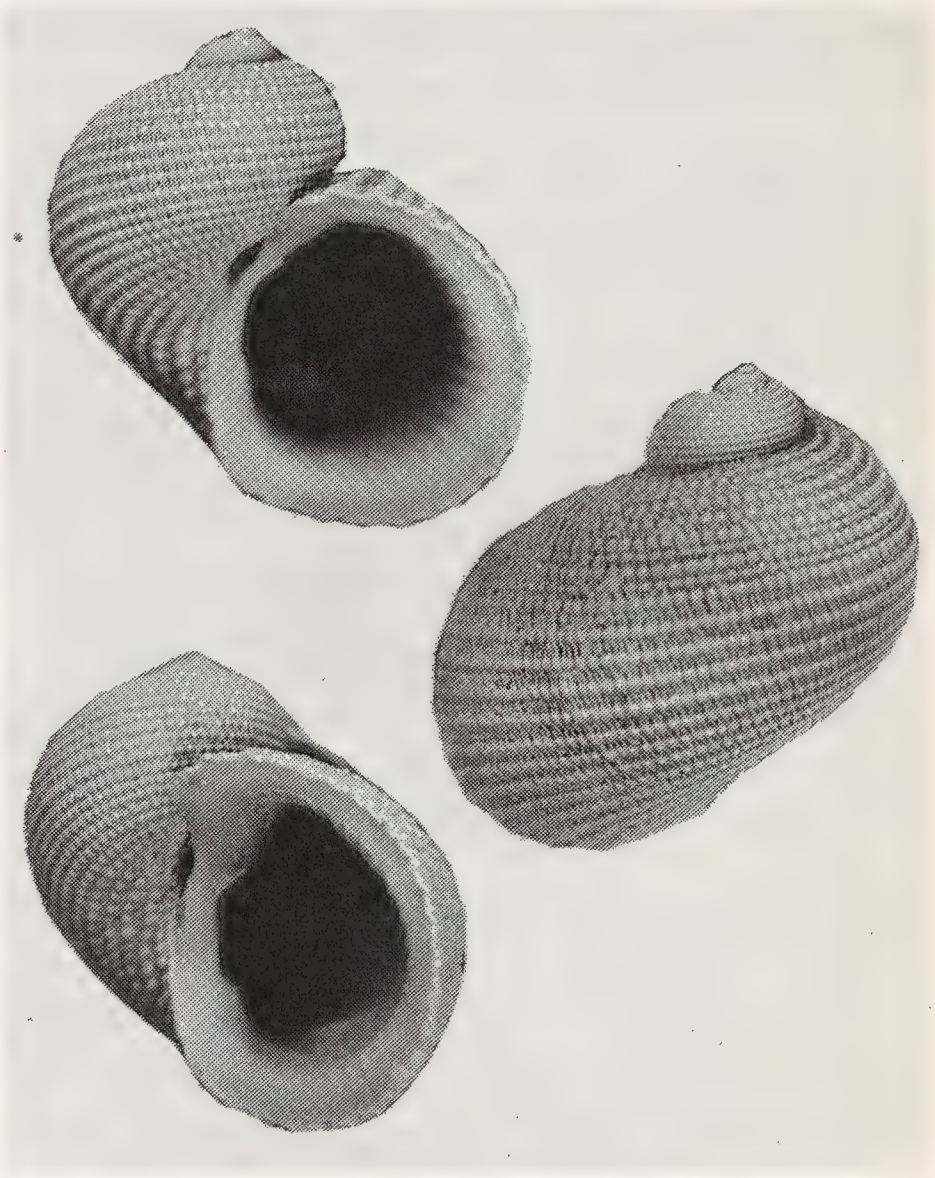
July 31, 1974

A RECENT CARIBBEAN SPECIES OF THE GENUS *NERITOPSIS* (MOLLUSCA: GASTROPODA)

ROBERT C. HOERLE
WEST PALM BEACH, FLORIDA

The writer's article regarding the first New World occurrence of the genus *Neritopsis* in the late lower Miocene Chipola Formation of northwestern Florida (Hoerle, 1972, p. 23) has had an interesting sequel. In early 1973 Thomas L. McGinty, of Boynton Beach, Florida, discovered the existence of a Caribbean species of *Neritopsis* in his collection of Recent mollusks. Subsequently Charles J. Finlay of Newark, Delaware, and Dan L. Steger of Tampa, Florida, produced additional specimens of this undescribed *Neritopsis;* all were collected by Mr. Finlay during the period from 1944 through 1953. To date a total of nine individuals have been located in the three collections and all are from the northern coastal area of Cuba. Collecting localities are between Banes, a small village located just west of Havana in easternmost Pinar del Rio Province, and Varadero, in Matanzas Province, about eighty miles east of Havana. The Chorrera Sands area near Havana yielded four specimens. Both the Banes and Chorrera Sands localities were large sandy banks created by extensive dredging for construction purposes while the Varadero site is a natural beach and the specimens were obtained there only after strong northwest winter storms.

These specimens previously have been misidentified as species of the families Neritidae or Vanikoridae, and understandably so, because of a number of reasons. Although there is a fair amount of literature available for the sole previously known Recent species, *Neritopsis radula* (Linné) of the Indo-Pacific region (*e.g.*, Cooke, 1895; Hirase, 1951; Kira, 1955 & 1962), none of the existing illustrations show the very distinctive apertural notch, which is one of the primary distinguishing characteristics of the genus. The Recent Caribbean specimens were all collected dead, and hence lacked the unusual trapezoidal calcareous operculum, the second characteristic. Further examination of other Caribbean collections should reveal additional specimens of this new species.



Text figure 1. *Neritopsis finlayi* R. C. Hoerle, n. sp. USNM 739425 (holotype), X 2.

Order ARCHEOGASTROPODA Thiele, 1931

Superfamily NERITACEA Rafinesque, 1815

Family NERITOPSIDAE Gray, 1847

Subfamily NERITOPSINAE Gray, 1847

Genus NERITOPSIS Grateloup, 1832

Neritopsis GRATELOUP, 1832, Actes Soc. Linn. Bordeaux, v. 5, p. 129; [1847] Conchyl. Foss. Bassin Adour, Neritines, pl. 1 [pl. 5], figs. 36-38. Type species: *Neritopsis moniliformis* Grateloup, by monotypy, [=*Radula* Gray, 1842; and (based on opercula) *Peltarion* Deslongchamps, 1858; *Cyclidia* and *Scaphandia* Rolle, 1862; *Rhynchidia* Laube, 1868].

NERITOPSIS FINLAYI R. C. Hoerle, n.sp.

Text figure 1

Diagnosis: Shell heavy, globose, spire high for the genus. One and one-quarter smooth nuclear whorls, three plus teleoconch whorls in adult specimens. Teleoconch ornament initiated by spiral threads and faint, sharp, widely-spaced axial growth lines for the first half turn, becoming stronger and forming beads. Nineteen to twenty-seven beaded, unevenly spaced, narrow spiral cords on final turn; interspaces of varying widths, ornamented by scabrous incrementals. Aperture circular; outer lip sharp, crenulated by spiral ribs, thickened within and marked with numerous short, coarse lirations. Inner lip heavily calloused with an elongaged square notch in central area. Umbilicus narrow, deep. Color grayish white. Operculum and soft parts unknown.

Dimensions of holotype: height 17.4 mm, diameter 15.9 mm.

Holotype: USNM 739425.

Type locality: Chorrera Sands, Havana, Cuba.

Occurrence: Recent only, north coast of Cuba.

Figured specimen: USNM 739425 (holotype). Other occurrences: Beach at Kilometer 27, Via Blanca Highway, Varadero, Matanzas Province, Cuba; Banes, Pinar del Rio Province, Cuba.

Discussion: Neritopsis finlayi is clearly distinguishable from both the Recent species *N. radula* (Linné, 1758), of the Indo-Pacific region, and *N. vokesorum* Hoerle, 1972, the fossil species of the Chipola Formation. While all three are heavy and globose and with beaded spiral cords there are marked morphological differences. *N. radula* is non-umbilicate; consisting of two and one-half teleoconch whorls; ornamentation commencing on first post-nuclear whorl with spiral cords only. *N. vokesorum* is slightly umbilicate; moderately high spired; three and one-half teleoconch whorls; the beaded sculpture is initiated immediately following the protoconch. *N. finlayi* has the highest spire of the three species; ornamentation on first post-nuclear whorl consisting of spiral cords and faint, but sharp, widely-spaced axial growth lines.

The development from the slight umbilicus of the Chipola species to the deep umbilicus of the Recent Caribbean form and the almost equal number of teleoconch whorls in the two indicates the close affinity of *Neritopsis vokesorum* to *Neritopsis finlayi.* The Indo-Pacific *N. radula* bears a great similarity to the European Miocene *N. moniliformis,* as was previously mentioned by the writer: "The resemblance of *N. moniliformis* to *N. radula* has led numerous authors in the past to synonymize the two species..." (Hoerle, 1972, p. 24). As these two forms have numerous morphological characteristics in common, it may be assumed that *N. moniliformis* is the ancestor of *N. radula.* The genus, although dating back to the European Mesozoic, is not known earlier than the lower Miocene in the New World and the manner in which the genus migrated to the New World is purely a matter of speculation.

This new species, *Neritopsis finlayi,* is dedicated to C. J. Finlay of Newark, Delaware, who kindly donated the specimen for the holotype, also a paratype that remains in the writer's collection. Acknowledgments are given to P. L. and T. L. McGinty and D. L. Steger, all of whom provided specimens for study. These paratypes will be distributed to scientific institutions by the aforementioned individuals.

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July 31, 1974

A NEW PLICATULID BIVALVE FROM THE LATE CENOZOIC OF SOUTHERN FLORIDA

GRAIG D. SHAAK

UNIVERSITY OF FLORIDA, GAINESVILLE, FLORIDA

and

DAVID NICOL

GAINESVILLE, FLORIDA

ABSTRACT

A new fossil plicatulid, *Plicatula hunterae,* is described, figured, and illustrated. This new species is erected on the foundations of five taxonomic characters, length, width, thickness, length/width/thickness ratios, and plication counts, measured from a suite of 61 specimens.

INTRODUCTION

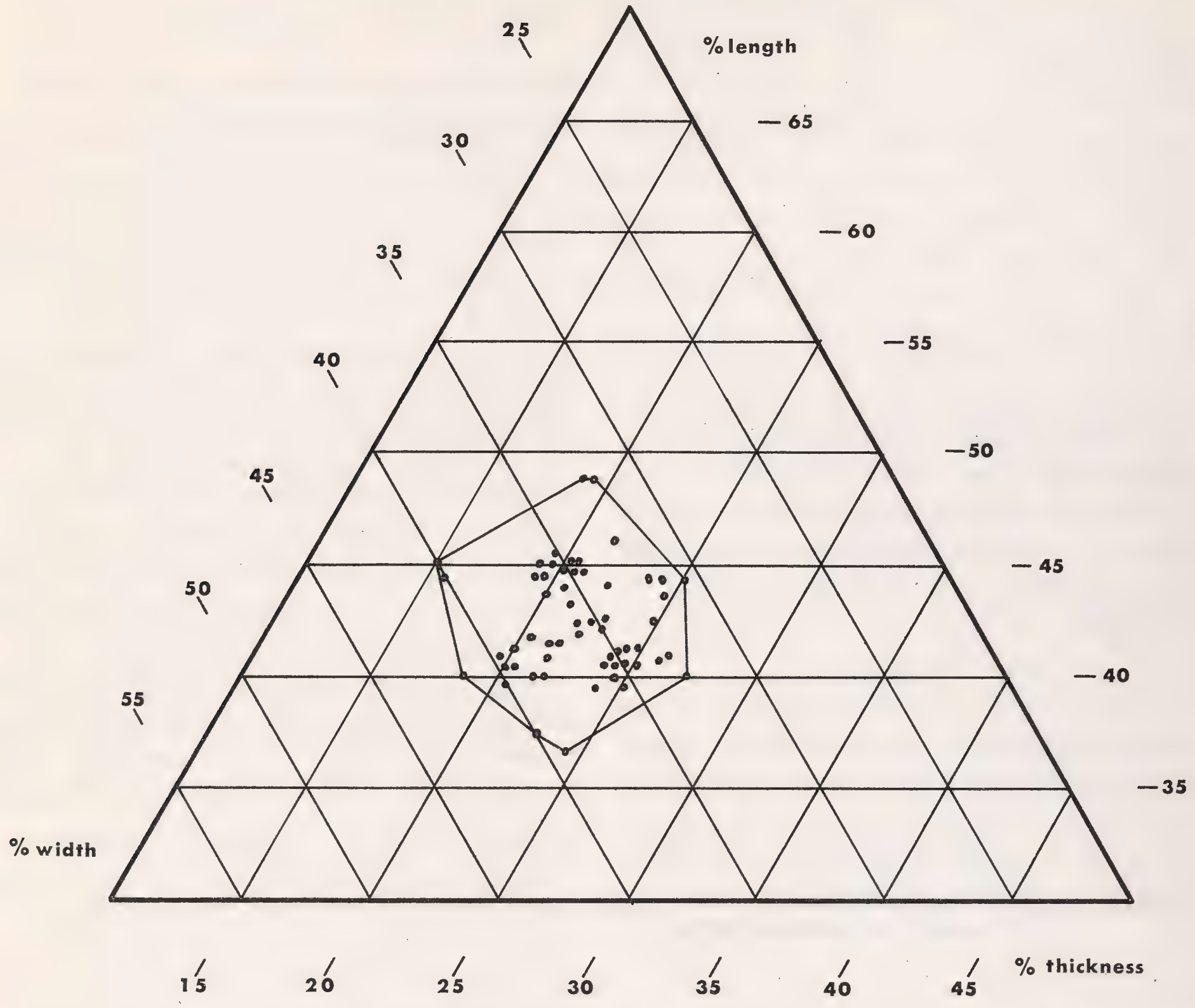
M. E. Hunter pointed out to us that a large *Plicatula* she and J. E. Banks collected from southern Florida was probably an undescribed species. This new species was among a large collection of fossils donated to the Florida State Museum by Coastal Petroleum Company, Inc. Additional specimens of the undescribed species of *Plicatula* have been collected by the senior author and by H. K. Brooks and his students from the University of Florida.

There is a difference of opinion as to the stratigraphic placement and geologic age of the collecting horizons. The particular zones in which the undescribed species of *Plicatula*

TABLE 1: Summary of measurements taken from 61 specimens of *Plicatula hunterae* n. sp. from the Late Cenozoic of southern Florida.

	Length*	Width*	Thickness*	Total*	%L	%W	%T	RIBS R	RIBS L
Total	3005.9	2541.7	1529.8	7078.4	2590.98	2191.00	1316.99	1216	1195
Mean	49.3	41.7	25.1	116.0	42.48	35.92	21.59	20	20
Median	50.3	42.7	25.5	----	42.00	36.00	21.00	19	20
Mode	bi-modal	bi-modal	bi-modal	—	42.00	36.00	21.00	19	20
Variance	0.525	0.399	0.254	2.829	4.920	5.676	5.545	15.928	17.412
Standard deviation	0.724	0.631	0.504	1.682	2.218	2.382	2.354	3.991	4.172
Standard error	0.092	0.080	0.064	0.215	0.284	0.305	0.301	0.511	0.534
Range	21.8-60.4	23.6-57.2	14.2-39.5	78.0-144.1	37-48	31-42	15-27	13-28	12-27

*Length, width, and thickness measurements are in millimeters.



Text figure 1. Length, width, and thickness triangular graph showing per cent of each value for 61 specimens of *Plicatula hunterae* n. sp.

is found at both localities are recognized as Pleistocene Caloosahatchee Formation by H. K. Brooks (personal communication) and Pliocene Pinecrest Beds by M. E. Hunter (personal communication). Thus, we refrain from making an exact stratigraphic placement and age determination.

This difference of opinion as to the exact age of many of the upper Cenozoic formations in the southern part of peninsular Florida has become a common occurrence. For at least the past ten million years, the rate of deposition of sediments in this region has been exceedingly slow (G.M. Griffin, Jr., personal communication). It would take a minimum of reworking, channel filling, sinkhole filling, and like processes to throughly mix together, in the same beds, fossils of Pliocene and Pleistocene age.Even the most detailed stratigraphic sections may not solve the problem of age determination of some of the beds in this region.

PLATE 1

Plicatula hunterae Shaak and Nicol, n. sp.

Figures

1–2. Holotype FSM 3655, length 59.7 mm, width 52.0 mm. Fig. 1, left valve exterior; Fig. 2, right valve exterior.

3–6. Paratype FSM 3656, length 55.4 mm, width 43.1 mm. Fig 3, left valve exterior; Fig. 4, right valve exterior; Fig. 5, left valve interior; Fig. 6, right valve interior.

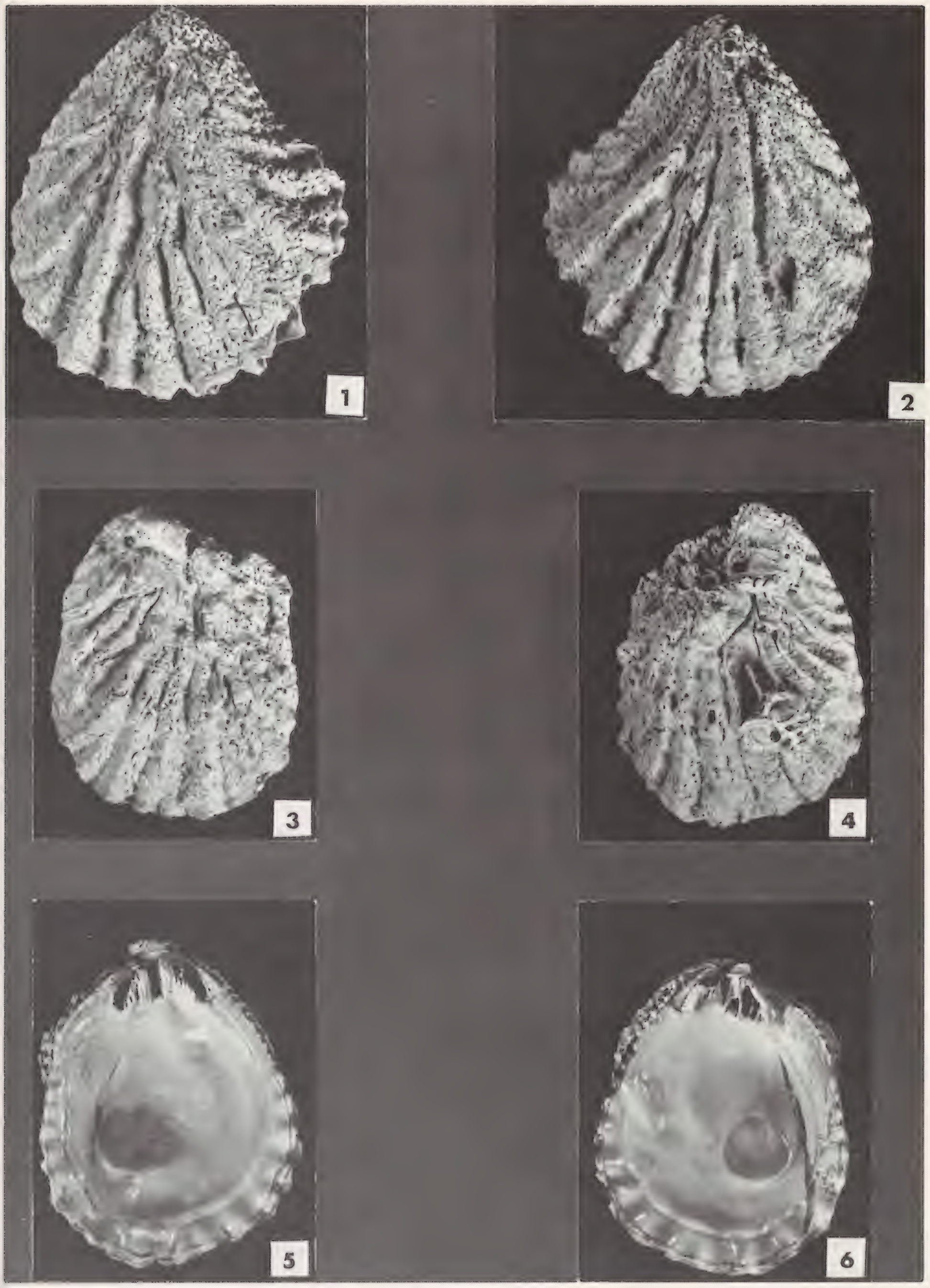


PLATE 1

SYSTEMATIC PALEONTOLOGY

Family PLICATULIDAE Watson, 1930

Genus PLICATULA Lamarck, 1801

Type species: *Spondylus plicatus* Linné, 1758; subsequent designation Schmidt, 1818 (according to Cox and Hertlein, 1969, p. N377). Recent.

PLICATULA HUNTERAE
Shaak and Nicol, n. sp.

Plate 1, figures 1–6

External features: Shells subtrigonal to irregular, subequally biconvex, compressed, inequivalved; averaging 49.3 mm in length, averaging 41.7 mm in width, averaging 25.1 mm in thickness (Table 1), length, width, and thickness ratios averaging 42, 36, and 22 per cent, respectively (Table 1, Text-figure 1); right valve larger and more convex; attachment scar on right valve generally near umbonal area; coarsely costate in a radial manner, changing to plicate near commissure, costae and plicae commonly bifurcating near commissure; both valves averaging 20 plicae intersecting commissure (Table 1); infrequent semitubular spines extending from plicae; prominent imbricating growth lamellae; several shells showing residual traces of color pattern.

Internal features: Cardinal area restricted; isodont crura, straight, diverging away from cardinal area, crenulated; resilium elongate triangular, deeply incised; monomyarian musculature, adductor scar posterior of midline; pallial line integripalliate, closely parralleling commissure.

Comparisons: There is only one species of *Plicatula* that resembles *P.hunterae*. Hertlein and Strong (1946, pp. 63-64) call this similar species *P.spondylopsis* Rochebrune, and it ranges from Pliocene to Recent in the Panamic Province. This species is well figured by Hertlein and Strong (pl. 1, figs. 15-16). Durham (1950, pl. 15, fig. 2) also figures this species as *P.spondylopsis*. However, Keen (1971, figs. 209, p. 95) figures Rochebrune's type specimen of *P. spondylopsis*, which is very different from the Hertlein & Strong and the Durham figured specimens of *P. spondylopsis*. Keen's figures are that of a round and flat *Plicatula* with many fine radial ribs. There is a probable undescribed species from the southern Florida Plio-Pleistocene that is similar to Keen's figures of *P. spondylopsis*. Unfortunately, we have only three valves of this species. Rochebrune's original description of *P. spondylopsis* (1895, p. 242) consists of a brief Latin diagnosis, and he does not figure the species. The measurements Rochebrune gives would most certainly fit Keen's figured specimen, but not those figured by Hertlein and Strong nor by Durham.

Keen (1971, p. 94) claims that *Plicatula spondylopsis* of Hertlein and Strong and of Durham is actually *P. inezana* Durham 1950. Durham's figures of *P. inezana* (pl. 13, figs. 1,3,6) do not appear to be the same species as the figures of *P. spondylopsis* given by Hertlein and Strong and by Durham. *P. inezana* seems to be a smaller-sized species, and the much more inflated right valve is unlike our specimens of *P. hunterae*. Specimens of *P. hunterae* resemble the upper two figures of species 207, page 95, of *P. inezana* by Keen but not the lower two figures of species 207, which are copies of two of the three figures of *P. inezana* figured by Durham in 1950. Whatever the proper name of the large Panamic species of *Plicatula* it differs from *P. hunterae* mainly in having more rounded and flatter radial ribs and a much more trigonal outline than almost all specimens of *P. hunterae*. *P. hunterae* is two or three times larger than almost all of the extant and extinct species of *Plicatula* that we have seen.

This species is named for Muriel E. Hunter.

Type specimens: Holotype FSM 3655 (figured); five paratypes USNM 647305; five paratypes PRI 29589-93; paratype FSM 3656 (figured), FSM 3751 balance of paratypic suite (USNM=United States National Museum; PRI=Paleontological Research Institution; FSM=Florida State Museum).

Localities: Warren Brothers Marl Pit, east of Sarasota, in Sec. 13, T36S, R18E, Sarasota County, Florida (type locality); spoilbank, at junction of levee 29, section one, and level 28, section five, ½ mile north of 40 Mile Bend, west of Miami on route 41, in sec. 16, T54S, R35E, Dade County, Florida.

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July 31, 1974

THE PLIOCENE HORSE *NANNIPPUS MINOR* IN GEORGIA: GEOLOGIC IMPLICATIONS

M. R. VOORHIES
GEOLOGY DEPARTMENT
UNIVERSITY OF GEORGIA, ATHENS

I. ABSTRACT

Two upper cheek teeth of the diminutive horse *Nannippus minor* (Sellards) were collected from "upland gravel" deposits of previously unknown age in eastern Taylor County, Georgia. The known geographic and geologic range of the species is restricted to the Hemphillian (middle Pliocene on the North American land mammal time scale) of the southeastern United States, all previous specimens having been collected from the Bone Valley Gravels in Florida. Major downcutting of Piedmont and Coastal Plain streams, at least in the vicinity of the fossiliferous exposure, began no earlier than 10 million years ago. The fossils provide the first definite evidence of Pliocene rocks in Georgia.

II. INTRODUCTION

In the long-continued debate about the erosional history of eastern North America during the Cenozoic, much controversy has arisen over the correlation of specific geomorphic events in the Appalichians with dated deposits on the Gulf and Atlantic coastal plains. Various "peneplains" and "erosional surfaces" have been dated, usually on conjectural grounds, as old as Cretaceous or as young as Pleistocene (see review in Thornbury, 1965). Especially problematical have been the various "upland gravels" that occupy interfluvial areas in the mountains, piedmont, and upper coastal plain. Precise dating of these notoriously unfossiliferous deposits would contribute in an important way to our understanding of the origin of the present topography. The present note records the occurrence of chronostratigraphically useful fossil mammals in upland gravels in west central Georgia and discusses their stratigraphic significance.

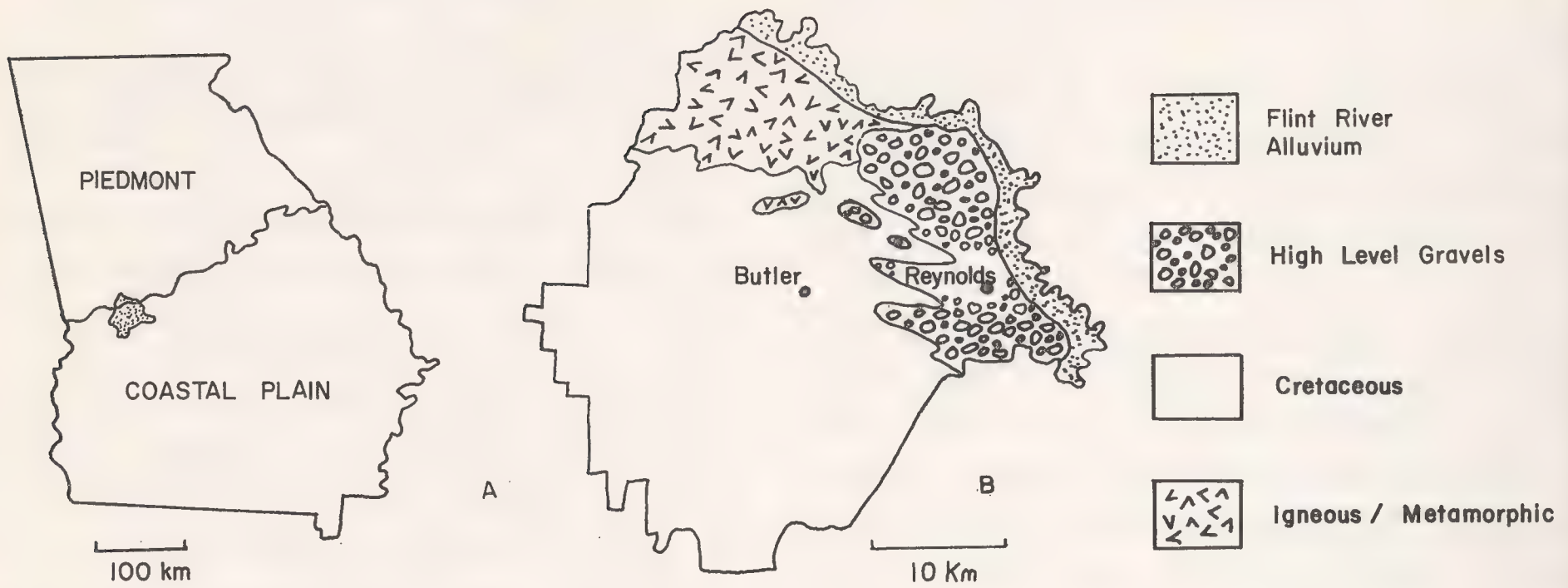
I wish to thank my wife, Jane, for help in collecting the fossils and in preparing the illustrations.

III. GEOLOGIC SETTING

The fossils described below were collected from an outcrop of moderately well cemented conglomeratic sandstone on the east side of Highway 128 near the southern city limits of Reynolds, Taylor County, Georgia (Fig. 1). The exposure is part of a unit mapped by LeGrand (1962) as "High-level gravels of Tertiary(?), Pliocene(?) age." these gravels form a cap over an area of about 50 square miles in northern and eastern Taylor County, in uplands west of the Flint River. The unit overlaps the Fall Line and rests unconformably on both crystalline rocks of the Piedmont and Cretaceous sedimentary strata of the Coastal Plain. No fossils have previously been reported from it.

At the productive exposure the strata may be described as a poorly sorted sandstone interbedded with lenses of polymictic conglomerate, the clasts in which are composed of quartz, chert, and claystone. It was in one of these lenses that the vertebrate fossils were found. Some of the bone fragments were badly abraded but the two horse teeth were fairly well preserved.

The high topographic postion of the upland gravels in Taylor County suggests that they once covered a considerably larger area, having been "dissected by erosion to such an extent that only in some interstream areas are they still preserved" (LeGrand, 1962). The deposition of the gravel thus predates much of the regional topography. As will be shown below, the age of the gravels near Reynolds is Pliocene. These Taylor County upland gravels are the first demonstrably Pliocene beds to be reported in Georgia. Marine or estuarine(?) sediments in extreme southeastern Georgia (Charlton Formation) are of suspected Pliocene age (Herrick, 1963, 1965), but the biostratigraphic evidence on this point has never been presented in detail. If indeed the Pliocene was a time of widespread erosion in Georgia, with deposition being limited to sheets of coarse gravel, then the scarcity of datable Pliocene marine strata is to be expected.



Text figure 1. A. Outline map of Georgia showing the location of Taylor County. B. Areal geology of Taylor County showing relationship of High-Level Gravels to underlying Piedmont crystalline rocks and Coastal Plain sedimentary strata. *Nannippus* teeth were collected at Reynolds in the east-central part of the county. Geology from LeGrand (1962). Gravels were previously of unknown age; now known to be Pliocene (Hemphillian), at least in part.

IV. SYSTEMATIC DESCRIPTION

Besides non-diagnostic fragments of turtle bone, the only fossils so far collected at the Reynolds exposure are horse teeth. The specimens are catalogued in the fossil collections of the Geology Department, University of Georgia.

Class MAMMALIA
Family EQUIDAE
NANNIPPUS MINOR (Sellards)
Text figure 2

Type—Florida Geological Survey no. 5867, an upper left premolar(?) from "a pit of the Amalgamated Phosphate Company at Brewster [Florida]." (Sellards, 1916, p. 96, plates 11 and 13.) Collected from the Bone Valley Gravel. Age: Hemphillian (middle Pliocene), see Webb and Tessman (1968).

Previously reported distribution—Bone Valley Gravel and equivalents in Florida.

Referred specimens—UGV-55, upper right P^4(?); UGV-56, upper right M^1 or M^2, from "High-level gravels" exposed along east side of Highway 128 at southern city limits of Reynolds, Taylor County, Georgia.

Description: UGV-55 (Fig. 2) is very similar to the holotype illustrated by Sellards (1916) but is at a slightly earlier stage of wear. At the occlusal surface the crown measures 15 mm anteroposteriorly and 13 mm transversly, compared with occlusal dimensions of 13.5 and 13 mm respectively in the holotype. 15 mm below the grinding surface (at a distance above the roots approximately equivalent to the height of the type specimen) the Georgia tooth measures 14 mm by 13 mm, almost exactly duplicating the size of the holotype. The basal portion of the mesostyle is damaged but its original height may be estimated as 38 to 40 mm at the present stage of wear; an unworn crown height between 50 and 60 mm may be estimated by assuming that the tooth is between 1/5 and 1/3 worn down.

The protocone is lenticular but would become oval with later wear as the ends become blunter. The lingual flattening of the protocone shown by the holotype would be duplicated by the Georgia specimen at a middle stage of wear. The protocone is completely free to the base of the tooth. The complexity of the fossette borders is slightly

less pronounced than that of the type (the fossettes are described as "very much complicated" by Sellards but, compared with other hipparionines, they are perhaps better characterized as moderately complex). Differences in detail are (terminology after Osborn, 1918): plipostfossette[1] triple in holotype, single in Georgia specimen; pli protoconule triple in holotype, single in referred specimen; pli caballin weak (wider than long) in holotype, twice as long as wide in Georgia specimen; and a tiny isolated enamel lake in the prefossette of the type is not present in the referred example. I consider all of these distinctions to reflect individual and/or ontogenetic variation which can be observed in any adequate sample of living or fossil equids and therefore of no taxonomic significance.

The hypoconal groove, as in the holotype, is completely open to the base of the tooth. The tooth is moderately curved with a radius of approximately 35 mm.

The upper molar (UGV-56) has been damaged by splintering although its occlusal surface is mostly intact. It appears to represent a different individual than the premolar described above because, although it is a first or second molar and therefore would have begun to wear earlier than a permanent premolar in the same animal, it is actually less worn than the previous specimen. It is smaller than the premolar as is usually true of molars; on the occlusal surface its transverse diameter is 10 mm. Breakage prevents measurement of the occlusal length. 15 mm below the grinding surface the transverse diameter has increased to 12 mm, still a remarkably tiny tooth considering its hypsodonty. As the base of the tooth is missing the original crown height cannot be measured but it must have been well over 40 mm because the preserved portion has a height of 39 mm. On the grinding surface the protocone has an elliptical shape with sharply attenuated ends; it is proportionately longer than that of the promolar. Both of these characters are strongly dependent upon the stage of wear: the protocone will become shorter and more oval in outline at later wear stages. At the occlusal surface the protocone bears a slight lingual indentation but this also fades out a

Text figure 2. Upper right 4th(?) premolar of *Nannippus minor* (Sellards), occlusal view. Specimen no. UGV-55 collected from High-Level Gravels, Taylor County, Georgia.

few mm below the surface. At the very early wear stage exhibited by this specimen the fossette borders are simple but corrugations of the enamel wall visible externally farther down the tooth crown indicate that crenulations would arise in the fossettes with further wear. No pli caballin is visible on the occlusal surface nor can one be seen at a break 25 mm below the surface where it could readily be observed if present. The presence of a pli caballin on premolars but not on molars is not uncommon in equid lineages and need not imply that the two teeth derive from different taxa. In at least some individuals of the late Pliocene and early Pleistocene species *Nannippus phlegon* the pli caballin is lacking on premolars as well (cf. Stirton, 1940, fig. 38).

V. DISCUSSION

Reference of these specimens to *N. minor* can be made with some confidence. No other species has such exceedingly small yet high crowned teeth. *Nannippus* (or *Hipparion,* see Webb and Tessman, 1968) *ingenuum,* the next larger hipparionine horse known from the southeastern United States, is 20 to 25% larger (Simpson, 1930) and may differ in occlusal pattern (Webb and Tessman, 1968,

report that a pli caballin is present except in late stages of wear in the cheek teeth of this species from the Manatee County Dam Site in Florida). *N. phlegon* is also considerably larger and appears to have a simpler enamel pattern.

N. minor was originally described as a species of *Hipparion* by Sellards in 1916 at which time virtually all horses with isolated protocones were placed in that genus. Simpson (1930) suggested that the species be transferred to Matthew's then new subgenus *Nannippus*. Stirton (1940) treated *Nannippus* as a new genus and included *N. minor* in it, a usage followed by most later workers. Morris Skinner (*in* Skinner and Hibbard, 1972) has cautioned against the common practice of assigning all small hypsodont horses with isolated protocones to *Nannippus*, apparently considering the genus to include only the type species, *N. phlegon*. Although I accept Skinner's exclusion of the *"gratus"* group from the genus, I prefer to include the other small, very hypsodont horses with characteristic hipparionine features (completely isolated protocone, fully open hypoconal groove) in *Nannippus*.

VI. AGE

Nannippus, excluding the *"gratus"* group for reasons discussed by Quinn, 1955, and Webb, 1969, is confined to rocks of Hemphillian and Blancan age (respectively, middle and late Pliocene on the North American land mammal time scale proposed by Wood, *et. al.*, 1941; see Berggren, 1972, for a recent attempt to intercalibrate the marine megafossil, microfossil, and land mammal time scales).

A Hemphillian age for the Taylor County gravels is suggested by the small size and relatively complex enamel pattern of the teeth described above compared to those of *N. phlegon*, the only adequately known Blancan species. *N. minor* is known from several localities in Florida (see Goin and Auffenberg, 1955; Webb and Tessman, 1968) all in rocks of Hemphillian age. The closest correlatives of the high-level gravels at Reynolds thus appear to be the Bone Valley Gravels of peninsular Florida. The lower part, at least, of the Citronelle Formation in Alabama has recently been dated as Hemphillian also (Isphording and Lamb, 1971).

VII. CONCLUSIONS

Two fossil teeth are admittedly a slender basis for dating widespread geomorphic events but as the first concrete evidence for dating any of the upland gravels in the Georgia Piedmont or upper Coastal Plain they at least deserve careful consideration. If the Hemphillian age of the Taylor County upland gravels can be extended by further work to beds in a similar topographic position in nearby areas, then the major downcutting of such rivers as the Flint and the Chattahoochee cannot have begun until Hemphillian or later. The Hemphillian began 10 million years ago according to an extensive series of potassium-argon age determinations on Hemphillian mammal faunas in the western U.S. (Evernden *et. al,* 1964). We may tentatively conclude that the sculpting of the Fall Line hills and other important features of the Georgia landscape required less time than this.

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July 31, 1974

RECENT BOOKS

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DESERT SEDIMENTARY ENVIRONMENTS, by K. W. Glennie. *Developments in Sedimentology,* volume 14, published by Elsevier Publishing Company, Amsterdam, London and New York, 1971, xv + 222 pp., illus., folding maps in pocket, $20.00

DATING THE PAST: An Introduction to Geochronology, by Frederick E. Zeuner. Published by Hafner Publishing Company, Darien, Connecticut, 1970, Fourth Edition, xx + 516 pp., atlas of 27 pls., 106 figs., $12.00

TERTIARY FAUNAS: A Text-book for Oilfield Palaeontologists and Students of Geology, Vol. I, the Composition of Tertiary Faunas, by A. Morley Davies, revised by F. E. Eames and R. J. G. Savage. Published by American Elsevier Publishing Company, Inc., New York, 1971, 571 pp., 1038 text-figs., $35.00

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THE PERMIAN REEF COMPLEX OF THE GUADALUPE MOUNTAINS REGION, TEXAS AND NEW MEXICO: A Study in Paleoecology, by Norman D. Newell, J. Keith Rigby, Alfred G. Fischer, A. J. Whiteman, John E. Hickox, and John S. Bradley. Published by Hafner Publishing Company, New York, 1972, xxi + 236 pp., atlas of 32 pls., 85 text-figs., $14.95

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THE MINOR STRUCTURES OF DEFORMED ROCKS: A Photographic Atlas, by L. E. Weiss. Published by Springer-Verlag, New York, Heidelberg, and Berlin, 1972, vii + 431 pp., 203 pls., index, $29.80

GEOLOGY OF THE MALAY PENINSULA (West Malaysia and Singapore), edited by D. J. Gobbett and C. S. Hutchinson. Published by Wiley-Interscience, New York, London, Sydney, and Toronto, 1973, xxi + 438 pp., illus., $45.00

FOSSILS AND THE LIFE OF THE PAST, by Erich Thenius, trans. by Barbara M. Crook. Published by The English Universities Press Ltd., London, and Springer-Verlag, New York, Heidelberg, and Berlin, 1973, xi + 194 pp., $5.90 (paper cover)

PERSPECTIVES IN THE HISTORY OF SCIENCE AND TECHNOLOGY, edited by Duane H. D. Roller. Published by the University of Oklahoma Press, Norman, Oklahoma, 1971, x + 307 pp., 29 figs., index.

This distinguished volume contains eight symposium papers accompanied by sixteen commentaries and two additional lectures presented as special events during the symposium at the University of Oklahoma on April 8–12, 1969. These twenty-six papers and commentaries by leading historians of science and technology offer a view of the research and present knowledge in these important areas.

—H.C.S.

REVIEW

HAMILTON M. JOHNSON
TULANE UNIVERSITY

PHYSICAL PRINCIPLES OF WATER PERCOLATION AND SEEPAGE, by J. Bear, D. Zaslavsky and S. Irmay. Published by UNESCO, France (distributed in the United States by Unesco Publ. Center, New York City), 1968, iv plus 465 pp., $20.00

This is Volume XXIX of the "Arid Zone Research Series," presenting the results of research which was part of Unesco's arid zone program started in 1951. The authors are staff members of the Faculty of Civil Engineering, Technion-Israel Institute of Technology, Haifa. It is thoroughly documented, indexed, and illustrated. The mathematical treatment is both rigorous and ubiquitous. Use of the book by geologists, even sedimentologists, is doubtful but it certainly would be of value to an engineer working with land drainage, irrigation, storage reservoirs, foundations, etc.

CERATOLITHUS ACUTUS GARTNER AND BUKRY, N. SP. AND *CERATOLITHUS AMPLIFICUS* BUKRY AND PERCIVAL— NOMENCLATURAL CLARIFICATION

STEFAN GARTNER
UNIVERSITY OF MIAMI, MIAMI, FLORIDA

and

DAVID BUKRY
U. S. GEOLOGICAL SURVEY, LA JOLLA, CALIFORNIA

ABSTRACT

The calcareous nannofossil *Ceratolithus acutus* Gartner and Bukry n.sp., is a birefringent certatolith from early Pliocene sediment. It is distinct from *Ceratolithus amplificus* Bukry and Percival, the holotype of which is from late Miocene sediment. *Ceratolithus dentatus* Bukry is a junior synonym of *C. amplificus*.

HISTORICAL BACKGROUND

Burkry and Percival (1971) described and named a large and robust representative of the genus *Ceratolithus*, the species *Ceratolithus amplificus*. They indicated that this species occurs in late Miocene and early Pliocene sediment in the Atlantic and Pacific Oceans. Subsequently, Bukry was able to distinguish two distinct taxa within the group of specimens formerly included in *Ceratolithus amplificus* and therefore restricted the name *Ceratolithus amplificus* to the early Pliocene form (Bukry, 1971, table 2). To the late Miocene form he gave the name *Ceratolithus dentatus* (Bukry, 1973).

In a study of the evolutionary lineage of the genus *Ceratolithus*, samples from the type levels of several ceratolith species have been re-examined. It was found that at its type level *Ceratolithus amplificus* is associated with the five-rayed symmetrical asteroliths of the *Discoaster quinqueramus* group, and hence the age of the type specimen is late Miocene. A careful examination of *Ceratolithus dentatus*, which was described from the same stratigraphic level elsewhere, indicated that the two are identical. The name *Ceratolithus dentatus* is, therefore, a junior synonym of *Ceratolithus amplificus*.

This error has left the distinctive early Pliocene form without a name, and the species is herein named *Ceratolithus acutus*.

SYSTEMATIC PALEONTOLOGY

CERATOLITHUS ACUTUS
Gartner and Bukry, n.sp.

Plate 1, figures 1-4

Description: Ceratolithus acutus is a robust species that has unequal or almost equal horns and a blunt apical spine that terminates in an acute angle. This apical structure is nearly symmetrical and may bear a ridge-like thickening that runs somewhat off center from near the tip of the apical structure towards the inner curvature. In the preferred orientation, with the plane of the ceratolith normal to the direction of illumination, *Ceratolithus acutus* is highly birefringent. Specimens are brightest when the horns are at about 45 degrees to the polarizing directions of the crossed nicols and go to extinction when the horns are parallel to the direction of polarization. On the surface of the longer horn three or more prominent nodes may be present, and on some specimens these nodes coalesce to form a ridge.

Remarks: Ceratolithus acutus is similar to the closely related species *Ceratolithus rugosus* in its optical properties in cross-polarized light. It differs in having a pronounced broad apical spine, which is generally well preserved even on corroded specimens. *Ceratolithus amplificus* is only weakly birefringent or non-birefringent, and has the apical spine more asymmetrically located.

Ceratolithus acutus was previously identified as *Ceratolithus amplificus,*however, the type level of the latter is in the upper Miocene, well below the extinction level of *Discoaster quinqueramus.* The highly birefringent ceratoliths, of which *Ceratolithus acutus* is the oldest do not appear in the geologic record until well above the extinction level of *Discoaster quinqueramus.*

Occurrence: Ceratolithus acutus is most common in lower Pliocene sediment. At Capo Rossello in Sicily this species occurs in the Trubi Formation from about 6 meters above the base to about 48 meters above the base. In the equatorial Pacific the species first appears near the middle of the lowermost reversed event in the Gilbert epoch in Core RC 12-66 and apparently ranges no higher than the Gilbert "b" event in Core V24-59, (Gartner, 1973).

Type specimen: Plate 1, figure 4.

Type locality: DSDP 22-214-9-3, 22-23 cm; Indian Ocean, lat. 11^0 20.21'S., long 88^{0}43.08'E., subbottom depth 79 meters.

CERATOLITHUS AMPLIFICUS
Bukry and Percival, emended

Plate 1, figures 5-7

Ceratolithus amplificus BUKRY and PERCIVAL, 1971, p. 125, pl.1, figs. 9-11.
Ceratolithus dentatus BUKRY, 1973, p. 676, pl.2, figs. 1-3.

Description: Ceratolithus amplificus is a robust strongly asymmetrical horseshoe-shaped species with a short but thick apical spine. The apical spine is located above the larger of the two horns with which it appears to be more or less continuous. The smaller horn has the appearance of a sharply curved hook at the tip of the extended apical region. On well-preserved specimens one surface of the large horn as well as the apical region may bear a line of rough nodes. On many specimens a ridge may be visible in place of the nodes. In the preferred orientation with the plane of the ceratolith normal to the direction of illumination *Ceratolithus amplificus* generally is nonbirefringent, tilted specimens may be weakly birefringent and the

---

PLATE 1

Figures 1–4

Ceratolithus acutus Gartner and Bukry n. sp.

1, 2. RC12-66; 1620 cm; X2500. 1 Interference contrast; 2 Cross-polarized light, with long axis of specimen at 45 degrees to direction of polarization.

3, 4. DSDP 22-214-9-3; 22-23 cm; X5000. Scanning electron microscope photographs.

Figures 5-7

Ceratolithus amplificus Bukry and Percival

5. DSP 22-214-12-3; 14-15 cm; X5000. Scanning electron microscope photograph.

6. DSDP 22-214-12-cc; X2500. Light-microscope photograph, phase contrast.

7. P6603-49, 1001 cm; X2500. Light-microscope photograph, interference contrast.

1

2

3

4

5

6

7

PLATE 1

orientation at which they are brightest varies, depending on the way the specimen is tilted.

Remarks: Ceratolithus amplificus is similar to *Ceratolithus acutus,* from which it differs by the more asymmetrical position of the apical spine, by having the horns farther apart and proportionately shorter and by the lack of strong birefringence in cross-polarized light. *Ceratolithus tricorniculatus* is also similar to *Ceratolithus amplificus* but the former is much more delicate. Although both species may be weakly birefringent, *Ceratolithus tricorniculatus* and *Ceratolithus amplificus* may be brightest with the horns parallel to the direction of polarization. Birefringence in both species is generally attributable to tilting of the specimens, which occurs frequently because of surface decorations of the species.

The pronounced curvature or hook formed by the smaller horn of *Ceratolithus amplificus* may give this species an angular appearance. The nodes on the surface of this species are no doubt the predecessors of the rods which form the proximal keel of *Ceratolithus cristatus.* An intermediate development of this accessory structure can be seen on some well-preserved specimens of *Ceratolithus acutus* and *Ceratolithus rugosus* also.

Occurrence: Ceratolithus amplificus occurs in late Miocene sediments in association with *Ceratolithus primus.* Its earliest occurrence is somewhat above the first occurrence of *C. primus,* and it disappears from the record at about the level of the first occurrence of *Ceratolithus acutus.*

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July 31, 1974

AGE OF PINECREST BEDS, SOUTH FLORIDA

W. H. AKERS

CHEVRON OIL COMPANY, NEW ORLEANS

The "Pinecrest beds" were first described by Olsson and Petit (1964, p. 516), who dated them as "late Miocene or Pliocene in age." Hunter (1968) assigned the Pinecrest Sand, the Ochopee Limestone, and the Buckingham Limestone to the upper part of the Tamiami Formation and proposed the correlation of the Tamiami Formation with the Jackson Bluff Formation of northern Florida, the Duplin Marl of South and North Carolina, and the Yorktown Formation of Virginia. Weisbord (1972, p. 60) published a section of the Pinecrest Formation in the Warren Brothers Pits at Sarasota, Florida, as measured and described by Harbans Puri.

Material studied for the present report was collected by Mr. and Mrs. Robert C. Hoerle from the Pinecrest beds at a locality described as follows by Dr. Harold E. Vokes (1969, p. 125):

> "Tulane locality 1000. Pinecrest beds, borrow pit at east end of 17th Street, 3.2 miles east of Tuttle Road, about 8 miles east of U. S. Highway 301 in Sarasota (T36S, R19E), Sarasota Co., Florida."

Washing of material from Tulane locality 1000 on a U.S. Standard Sieve number 200 produces a residue of mainly quartz sand and mollusk fragments in which at least a dozen species of ostracodes and a benthonic foraminiferal fauna of littoral origin are present. Planktonic foraminifera are rare. Only *Globigerina bulloides* and *Globorotalia inflata* were identified in the material by the writer.

The following species were identified in a sparse flora of calcareous nannoplankton:

Braarudosphaera bigelowi (Gran and Braarud)
Coccolithus doronocoides Black and Barnes
Coccolithus pelagicus (Wallich)
Cyclococcolithina leptopora (Murray and Blackman)
Cyclolithella annula (Cohen)
Gephyrocapsa caribbeanica Boudreaux and Hay
Gephyrocapsa reticulata Nishida
Helicopontosphaera kamptneri Hay and Mohler
Reticulofenestra pseudoumbilica (Gartner)
Sphenolithus abies Deflandre
Syracosphaera pulchra Lohmann
Umbilicosphaera mirabilis Lohmann

Braarudosphaera bigelowi and *Helicopontosphaera kamptneri* are the most frequent components of the flora.

Fortunately, several species occur in the formation that are diagnostic for geologic age. These are *Gephyrocapsa caribbeanica, Reticulofenestra pseudoumbilica,* and *Sphenolithus abies.* Concurrence of these three species is in Neogene Zone 20 of Blow (1969), and the overlap of the ranges of these nannofossils thus argues strongly for a middle Pliocene age for the Pinecrest beds (Figure 1).

The ranges of the late Cenozoic Coccolithophoridae are based on the extensive investigations of the Deep Sea Drilling Program. Earlier concepts of coccolith biostratigraphy have been modified and improved in the light of paleoclimatic control afforded by borings in virtually all latitudes (Wise, 1973, p. 126), and precise age assignments are now possible for most marine beds by calcareous nannoplankton.

Other Neogene formations of the Atlantic Coastal Plains of the United States and Mexico have been studied for planktonic foraminifera (Akers, 1972) and dated as lower to middle Pliocene. Even more precise dating is now afforded by calcareous nannofossils (Akers and Koeppel, 1973) for the Yorktown, Jackson Bluff, Concepcion, and Agueguexquite formations with which the Pinecrest Formation is correlated. All are assigned to Zone N. 20.

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The writer thanks Mr. and Mrs. Robert C. Hoerle of West Palm Beach, Florida, for carefully collected material from the Pinecrest beds at Sarasota. Drs. Harold E. Vokes and Emily H. Vokes supplied much of the incentive for the writing of this report by their interest in all data pertinent to the paleontological collections amassed and studied by them at Tulane University. Mr.

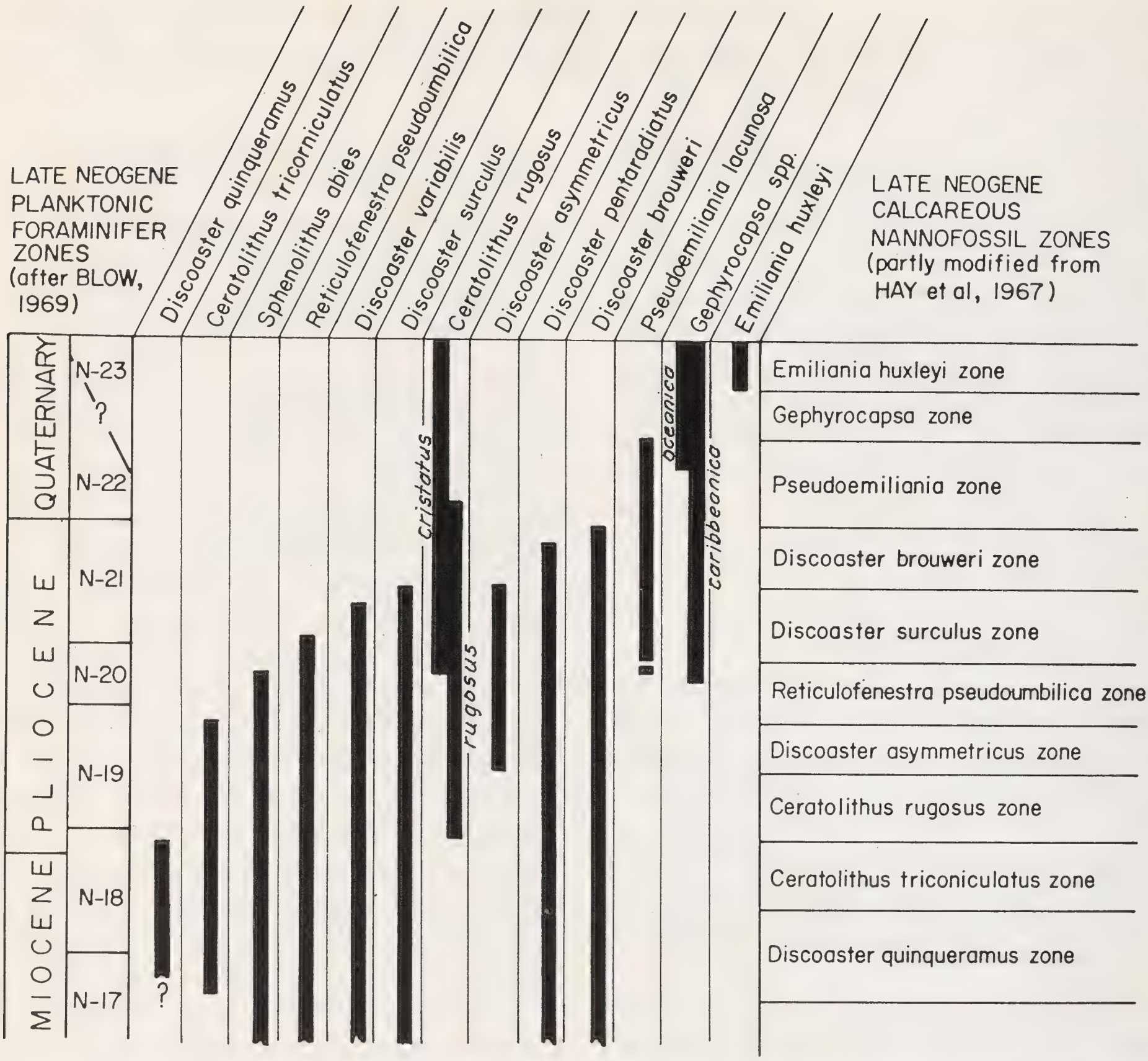

Figure 1. Ranges of some important Neogene calcareous nannofossil species, and correlation of nannofossil zones with planktonic foraminifer zones. MODIFIED AFTER GARTNER (1969).

Paul E. Koeppel assisted in both the light microscopy and Stereoscen examination of the material. Research for this project was supported by Chevron Oil Company.

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WEST PALM BEACH, FLORIDA

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EMILY H. VOKES
TULANE UNIVERSITY

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I. ABSTRACT

The two muricine genus-groups *Aspella* Mörch and *Dermomurex* Monterosato share certain unusual shell-characters that suggest they had a common ancestor, but it has not been recognized. The two groups begin almost simultaneously in geologic time: *Dermomurex* is slightly older, occurring first in the early Oligocene of Mississippi then in the late Oligocene of western France, the latter together in time, although not in space, with the first *Aspella* in the late Oligocene of southern France. There are numerous species of both genera found in many parts of the world throughout ensuing time. In the Recent

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A. MYRA KEEN, Department of Geology, Stanford University (Emeritus), Stanford, California
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fauna *Aspella* occurs in both the eastern and western Pacific Ocean, in the Indian Ocean, and in the western Atlantic. There are no living eastern Atlantic or Mediterranean forms known. *Dermomurex* is well represented in the New World by eight species, either eastern Pacific or western Atlantic. There are but three Indo-Pacific species, plus the type of the genus found in the Mediterranean. Five of the Recent species are placed in *Dermomurex* s.s., two each in the subgenera *Takia* Kuroda, *Trialatella* Berry, and *Gracilimurex* Thiele, and one in *Viator* Vokes.

In this paper the western Atlantic species are treated systematically, but there is only one member of *Aspella* as yet described, *A. senex* Dall, a Pliocene to Recent form often confounded with the Indo-Pacific *A. anceps* (Lamarck). Because of the undue amount of confusion over the Recent species of *Aspella* s.s., several of the Indo-Pacific species are illustrated for comparison with the western Atlantic *A. senex.*

There are eleven western Atlantic species assigned to *Dermomurex,* ranging in age from early Oligocene to Recent. Of these, three each are placed in the subgenera *Dermomurex* s.s., *Trialatella,* and *Viator,* and one each in *Gracilimurex* and *Takia.* Of that number five are new species described herein: *Dermomurex (Dermomurex) matercula, D. (Trialatella) farleyensis,* and *D. (? Viator) curviductus,* all from the late lower Miocene Chipola Formation of northwestern Florida; *D. (Takia) cookei,* from the early Oligocene of Mississippi; and *D. (Trialatella) antecessor,* from the Pleistocene of Florida and Costa Rica.

II. INTRODUCTION

The systematic position and relationships of the groups treated in this paper have been subject to a great deal of shifting about over the years. *Aspella* was originally named in the Ranellidae (= Bursidae) because of its two-varixed form; *Dermomurex* was placed in the Muricinae because of its three or six-varixed form. Later, the chalky outer layer that is so characteristic of both seemed to indicate placement in the Trophoninae (Cossmann, 1903, p. 55).

The writer once made the statement (Vokes, 1964, p. 29): "The genus *Aspella* seems to be intermediate between the Muricinae and the Tritonaliinae [Ocenebrinae] with the operculum of the first and a radula which is closer to the second." The basis of this statement was Troschel's illustration of the radula of *"Murex alveatus,"* which at that time was the only radular drawing available believed referrable to the group. The identity of *"Murex alveatus"* was somewhat uncertain but it was thought to be an *Aspella.* Further work has shown *M. alveatus* to be an older name for *M. intermedius* C. B. Adams, from the Caribbean, and both it and *M. erosus* are now considered to belong to the genus *Favartia,* subgenus *Caribiella,* of the subfamily Muricopsinae (Radwin and D'Attilio, 1971, p. 64). Radular drawings subsequently provided the writer by Messrs. Radwin and D'Attilio show an unequivocal muricine radular type for all of the species of *Aspella* and *Dermomurex* thus far investigated.

Keen (1971, p. 296) erected a subfamily Aspellinae to include not only *Aspella* and its kin, but also *Eupleura, Calotrophon, Attiliosa, Favartia,* and *Phyllocoma.* As the writer has discussed previously (Vokes, 1971a, p. 7, footnote), the need for this subfamily has not been adequately demonstrated.

The most recent suggestion for subfamilial placement was that of Radwin and D'Attilio (1971, p. 59), who, because of the chalky outer layer, concluded that the Typhinae might also include *Aspella* and *Dermomurex.* There is a certain logic in placing the aspelloids in the Typhinae, inasmuch as both groups do possess the chalky layer. This coating has been the subject of a paper by D'Attilio and Radwin (1971) and these authors proposed the name INTRITACALX for the layer. As they point out, the intritacalx is perhaps best developed in *Aspella, Dermomurex,* and certain typhine genera, but it occurs almost at random among the Mollusca, being found in at least four families of Gastropoda and three families of Bivalvia. So the presence of an intritacalx is hardly justification in itself for familial placement. The shells of the Typhinae also

possess buttressed sutures, which may be homologous to those in *Aspella* and *Dermomurex,* or they may be an analogous development in response to certain ecologic or morphologic conditions. Both groups have a "normal" muricine radula and on radular bases alone there would be no justification in separating either group from the Muricinae. The principal distinguishing character of the Typhinae always has been considered to be the anal tubes that are essentially confined to this group and there seems no value in disturbing this otherwise simple arrangement.

Therefore, it seems the best solution to include members of *Aspella* and *Dermomurex* in the subfamily Muricinae. The radula and the operculum are both completely compatible with this placement, and the shells, except for the heavy intritacalx, are not significantly different.

The close affinities of *Aspella* and *Dermomurex* were recognized first by Dall (1889, p. 206), who made *Aspella* a subgenus of *Trophon,* and *Dermomurex* (under the name *Poweria)* a synonym of *Aspella.* More recently workers have favored treating *Dermomurex* as a subgenus of *Aspella,* the writer having followed this scheme until the present paper. However, work on the geologic history of the two groups has convincingly demonstrated that, although the two groups do share certain marked resemblances, they have been separate and distinct for such a long time that the more accurate picture is to treat them as parallel genera*. Undoubtedly they had a common ancestor in the lower Tertiary but nothing is known of it.

In the early Oligocene beds of Mississippi we find the first aspelloid species, here referred to *Dermomurex (Takia) cookei,* n.sp. In the late Oligocene (Stampian) of western France (at Pierrefiette, near Nancy) there is a second species, which is very close to *D. cookei,* named *"Murex" cotteavi* Meunier, 1880. Simultaneously in the Stampian beds of southern France (at Gaas, near Dax), we find the first species of *Aspella* s.s. From this initial

Text figure 1. *Aspella senex* Dall. Dry Tortugas, Florida. X35.

appearance the two lines have been completely distinct.

In the early ontologic development of *Aspella* s.s. the shell has six varices but as the animal grows larger four of these are lost and appear only as buttress-like structures across the suture, connecting the lower whorl with that above it. In some species two of the four may continue in a weakened state but the shell develops a characteristic bilaterally-flattened shape (see pl. 1, figs. 12 and 13). In *Dermomurex* the species also start with six varices per whorl, and the Oligocene species continue through their entire development with six. However, two lines branch off the ancestral stock in the lower Miocene and in both of these there is eventually the loss of every other varix, with the consequent development of an adult shell having three varices and three inter-varical buttresses per whorl (see pl. 2, figs. 4 and 5).

In *Dermomurex* and in *Aspella* the protoconch is large, usually of one and one-half bulbous whorls. On the first post-nuclear whorl there are six small crescentic varices that overlap onto the protoconch (see text fig. 1). This is exactly

*The genus *Aspella* thereby becomes a genus without subgenera. But it will continue to be cited as "*Aspella* s.s." in this paper to prevent possible confusion.

the same type of early development that occurs in the *Poirieria-Pterynotus* line and it is, therefore, assumed that the members of the two groups were derived from a *Poirieria*-like ancestor. The modern representatives of *Poirieria* and its subgenera still exhibit a thin layer of intritacalx further corroborating this assumption. The Oligocene members of *Dermomurex* s.s. are not too dissimilar from the contemporaneous members of *Panamurex,* which is a side-branch of the *Poirieria* line, and the confusion we shall see between members of *Panamurex* and *D. (Viator)* can be more easily understood if this relationship is assumed to exist. The species of *Panamurex* in the early Miocene Chipola Formation have a fairly heavy intritacalx, although it is usually to be seen only on juvenile shells, suggesting that it is more fragile than the normal aspelloid intritacalx.

The history of the Muricinae has been discussed at length in another paper (see Vokes, 1971b). Briefly summarized: we find in the Paleocene beds of North America members of *Paziella, Poirieria,* and *Pterynotus* all occurring together. The three lines continue through time into the Recent fauna with essentially no change, but along the way certain side branches have appeared. Prior to the beginning of the Oligocene epoch the *Panamurex* and *Dermomurex* lines must have diverged independently as there are marked differences between the two early species *Poirieria (Panamurex) macneili* Vokes and *Dermomurex (Takia) cookei,* n.sp., which occur in the Oligocene beds of Mississippi. Morphologically the later members of *Panamurex,* especially *P. clarksvillensis* (Mansfield), have a strong resemblance to the members of *Viator,* a subsequent development from *Dermomurex,* but as both are derivative forms it is probably due to convergence.

Compared to other groups within the Muricinae, the aspelloids are small in number. There has never been any great period of abundance either in numbers of species or of individuals, so far as the fossil record reveals. The greatest number of species, not surprisingly, is in the Recent fauna, with five described species of *Aspella* (G. E. Radwin has a paper in press adding several to this total) and twelve species of *Dermomurex* (five in *Dermomurex* s.s., two each in *Takia, Gracilimurex,* and *Trialatella,* and one in *Viator).* In a sense it seems unnecessary to distribute such a few species, a total of 10 in *Aspella* and 32 in *Dermomurex,* into so many subgeneric units, but the geologic history of the group seems to warrant it.

Each line has been separate since the early Miocene and the small number of known species may well be a reflection of the lack of preservation of fossil aspelloids. In the Recent fauna most of the species occur in shallow water, frequently under or among stones. The preference for a littoral environment is not conducive to preservation, as can be readily ascertained from the lack of neritids as fossils in contrast to the great numbers to be found on any rocky shore. At Barra de Navidad, Jalisco, Mexico (TU R-166) the writer collected almost 100 specimens of *Aspella pyramidalis* within the period of one extremely low tide, so it is obviously not a "rare" species. But the total number of fossil examples of *Aspella* s.s. in the entire world probably all would fit comfortably in a small teacup. Most fossil species are represented by one or two specimens; *A. senex,* the most abundant, is represented in the Tulane Collections by a total of eight specimens, augmented by the loan of another 20 specimens from various friends. Attempts to borrow Recent examples from museum sources met with notable lack of success.

The *Dermomurex* group is little better, although most collections have a few Recent specimens. The single most abundant fossil species is *D. engonatus* (Dall) but in general most species are again represented by just a very few specimens.

The relationships between the various lineages of the two genera *Aspella* and *Dermomurex* are illustrated diagramatically in tables 1 and 2.

ASPELLA: The species at present referred to the genus *Aspella* s.s. were for the most part originally named as *Ranella* because of the most conspicuous morphologic feature of the genus, the paired row of varices aligned on either side of the spire. The first species named was *Ranella anceps* Lamarck, 1822, and it was this name that was given as the type of the genus by Mörch, 1877. However, the identity of Lamarck's species has been subject

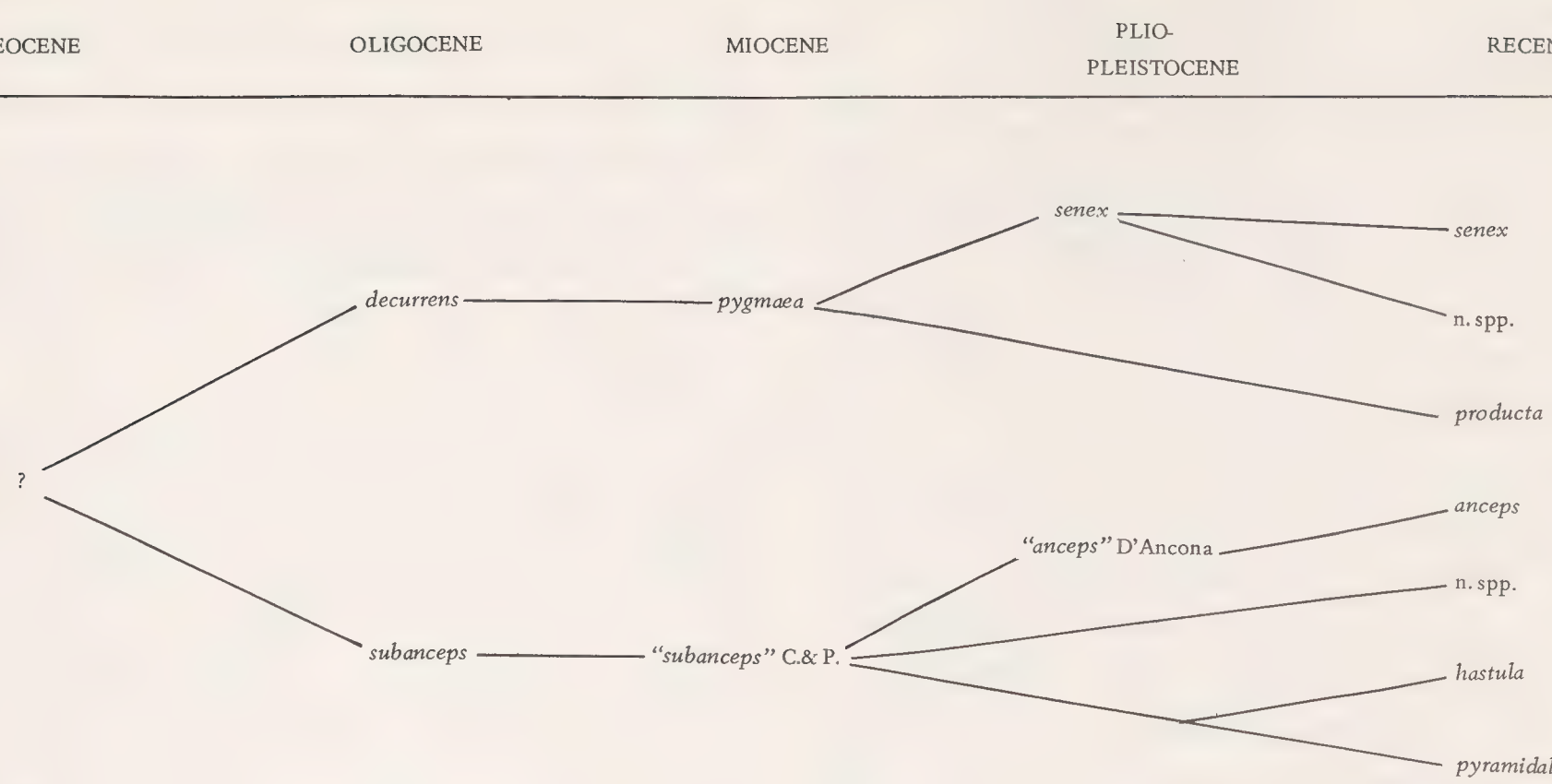

TABLE 1. Inferred relationship of the species of ASPELLA.

to much confusion because of the lack of either a locality or any reference to a figured specimen. The second species of *Aspella* that was described was *Ranella pyramidalis* Broderip, 1833, and this form with its East Pacific locality was considered by many to be the same as Lamarck's *R. anceps.* The description given by Lamarck, however, has the words *"nitida, alba"* (shiny, white), indicating that the specimen he had before him was not the same as *A. pyramidalis,* for the latter is not white at the same time that it is shiny. When the intritacalx is present on *A. pyramidalis* it may be a dirty dull chalky-white, although it usually is a yellowish color and usually has fine brown lines (see pl. 1, fig. 10). When worn and the intritacalx is no longer present, the shell is shiny but then the underlying color, which is mostly brown or rarely a dingy cream, is revealed (see pl. 1, fig. 11). Kiener (1842, p. 37) was the first to place the two species in synonymy, and as a result gave "les côtes du Pérou et celles de Panama" as the type locality for *"Ranella" anceps.* This was echoed by Reeve (1844, *Ranella,* pl. 8, expl.) who figured another specimen of *A. anceps,* but placed *A. pyramidalis* in synonymy, noting that "the longitudinal line which Mr. Broderip describes as traversing the whole length of the shell, both on the upper and under sides, is somewhat imaginary. It is suggested, no doubt, by the natural elevation of the sutural plates [buttresses], and has no analogy with the varices." Such is not the case for the "longitudinal line" is very real, as can be seen in pl. 1, figs. 5b, 6b, and 13b, and it is the vestige of a former varix (see pl. 1, fig. 12).

As a direct result of this confusion between *A. anceps* and *A. pyramidalis,* there is one unnecessary name for *A. anceps, "Ranella" acuticostata* Turton, 1932, which that author states "is a common S. African shell, and has usually been identified as *Ranella* (or *Aspella) anceps* Lamarck, but Bartsch says definitely it does not agree with the *anceps* from the west coast of America, which is the type locality." (1932, p. 109, pl. 14, fig. 789). Comparison of the South African shell (see pl. 1, fig. 5) and Kiener's illustration of Lamarck's species is completely convincing, to this writer at least, that the South African specimen is indeed the true *Aspella anceps.*

Aspella s.s. has a long geologic history, first appearing in the Oligocene beds of Dax, France. Here we see two similar although distinct species, one of which was originally called *"Ranella anceps"* by Grateloup (1847, pl. 24, figs. 28, 30). As the species is probably not true *anceps* it was renamed *Ranella subanceps* d'Orbigny, 1852. The second Oligocene species of *Aspella* s.s. was named as *"Fusus" decurrens* by Grateloup (*ibid,* pl. 24, figs. 43, 44). In the Burdigalian beds of France there is another species that was cited by Cossmann and Peyrot (1923, p. 234, pl. 12,

figs. 24, 25) as *"Eupleura" subanceps,* but it does not seem to be the same as the shell figured by Grateloup. The Burdigalian species resembles *A. hastula* (Reeve, 1844), being covered with small granules. This same form is also figured by Hörnes (1856, pl. 21, fig. 6) as *"Ranella anceps"* from the Tortonian beds of Steinabrunn, Austria. At the same time another species appeared that is almost certainly ancestral to the *A. producta* line, *"Ranella" pygmaea* Bellardi, 1873, from the middle Miocene of Italy (*Ranella emmae* Boettger, 1901, from the middle Miocene of Rumania, is the same). This species has a much wider shell than the true *A. anceps* and closely resembles the Caribbean *A. senex*. The *"R. anceps"* figured by Hoernes and Auinger (1885, p. 190, pl. 24, fig. 3) said also to be from Steinabrunn, is probably *A. pygmaea.* The *"Aspella anceps"* figured by Friedberg (1912, p. 183, pl. 11, fig. 16) from the Miocene of Poland is not any species of *Aspella* s.s. but is a specimen of *Dermomurex (Takia) distinctus* (Cristofori and Jan, 1832). In the Pliocene beds of Italy another undescribed form occurs. The specimen figured by D'Ancona (1873, pl. 10, fig. 5) as *"Ranella" anceps,* from Orciano Pisano (south of Pisa), is not the same as either the species of Hörnes or of Doderlein (the latter being *A. pygmaea,* well figured by Montanaro, 1935, pl. 7, fig. 6), although D'Ancona places both of these references in his synonymy. Neither, however, is it *A. anceps,* the shell being somewhat broader, with a marked angle at the shoulder in contrast to the "streamlined" appearance of the Recent species. So far as is known the line is now extinct in the eastern Atlantic and Mediterranean area.

In the New World the species *A. senex* Dall first appears in the Pliocene Pinecrest beds of Florida. There are no other western Atlantic *Aspella* s.s. known until the Recent, where we still find *A. senex* (frequently cited as *A. anceps*), along with three as-yet undescribed species. On the west coast of tropical America we see *A. pyramidalis* (Broderip) (pl. 1, figs. 10–13), and another undescribed species (that figured by Keen, 1958, fig. 376, as *A. pyramidalis*), which is the "cognate"* of *A. senex* (pl. 1, fig. 9). These new species are all to be described by George Radwin and are mentioned here for the sake of completeness. The only other New World species of *Aspella* is *A. hastula* (pl. 1, fig. 8), endemic to the Galapagos Islands. All of these forms are here figured for comparative purposes.

In the Indo-Pacific region we find there are two morphologic types present. One is the typical slender *A. anceps* (pl. 1, fig. 6), which as noted above is the same as *A. acuticostata* (Turton) from South Africa, and which also occurs in Australia at least. The specimen figured by Ponder (1972, pl. 23, fig. 7) is that species, as is confirmed by other specimens from New South Wales in the collection of the writer. Other localities are not certain. The second species, which seems to be the more common one, has been named *Ranella producta* Pease, 1861, and *Bursa lamellosa* Dunker, 1863. Although *"B." lamellosa* was figured by Dunker in the *Novitates Conchologicae* (1866, pt. 6, pl. 18, fig. 6) and refigured by Tryon (1881, Ranelliane, pl. 24, fig. 67), the type of *A. producta* was not figured until 1965 by Kay (1965, pl. 6, fig. 17, 18). From these illustrations it can be seen that *A. producta* is the correct name for the larger, more inflated form that is widespread throughout the Pacific Ocean. It has been taken at Hawaii (type locality of *A. producta*), Japan (type locality of *A. lamellosa*), Australia (Ponder, 1972, pl. 23, fig. 8), and Reunion Islands (Coll. MCZ) to the writer's certain knowledge. The East Pacific species, mentioned above as the "cognate" of *A. senex,* is a member of the *A. producta* line, but it is not, as stated by Ponder (*ibid.*, p. 229), the same species.

Thus we find there are two distinct lines of *Aspella* s.s., which go back to the Oligocene ancestors. One of these we might term the *"anceps"* group, which begins with the species *"Ranella" subanceps* d'Orbigny and today includes *A. anceps* from the Indo-Pacific region, *A. pyramidalis* from the East Pacific,

*For a discussion of the merits of the word "cognate" *vs.* the more commonly used "analog" see Radwin, 1969, Trans. San Diego Soc. Nat. Hist., v. 15, no. 14, p. 233.

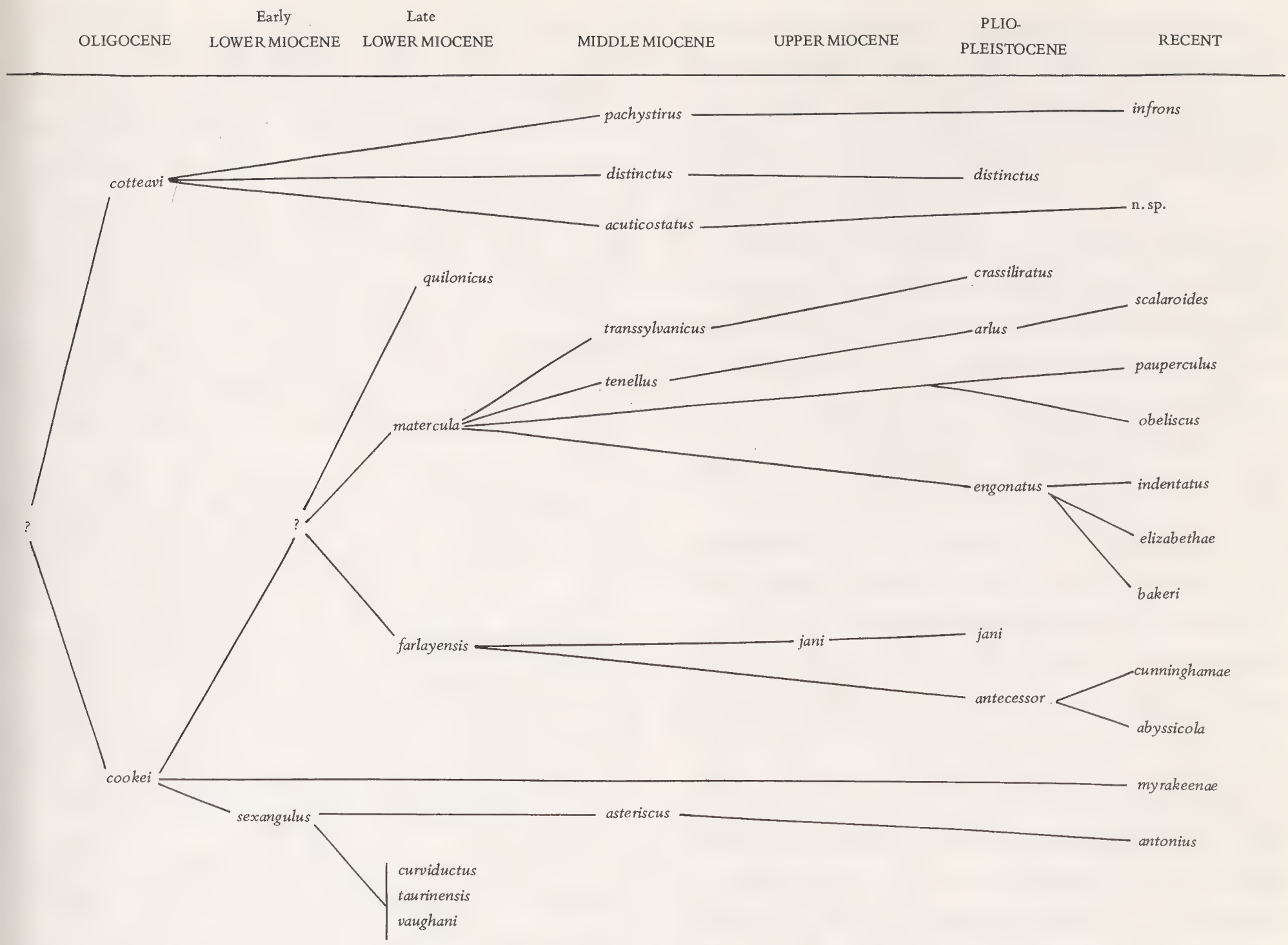

TABLE 2. Inferred relationship of the species and subgenera of DERMOMUREX.

and *A. hastula* from the Galápagos Islands. The second group, that of *A. producta,* begins with *"Fusus" decurrens* Grateloup, includes *"R." pygmaea* Bellardi, and today consists of *A. producta* from the Indo-Pacific area, *A. senex* from the Caribbean, and *A.* "species" from the East Pacific.

DERMOMUREX: Although all of the species assigned to this genus are clearly akin, there are some marked morphological distinctions among the various lines, and these have given rise to confusion in the nomenclature of the group. The species almost all originally were named as *"Murex,"* due to the presence of the three or six varices that characterize the group. The earliest name is *Poweria* Monterosato, 1884; however, this proved to be preoccupied by a genus of fishes, and so was re-named in 1890 by Monterosato as *Dermomurex.* The type-species was originally designated by Monterosato as *"Murex" scalarinus* Bivona-Bernardi, from the Mediterranean.

There have been several names proposed for this Recent Mediterranean species, in part due to its variability, but also due to the coincidence of several people working on the Mediterranean fauna at almost the same time. Thus we find in a short interval three names: *"Murex" scalaroides* Blainville, 1829; *"M." scalarinus* Bivona-Bernardi, 1832; and *"M." leucoderma* Scacchi, 1836. During the same period we have *"M." distinctus* Cristofori and Jan, 1832, which although named for a Pliocene fossil, has been synonymized by many authors with the Recent species. In addition, there are emendations of *M. scalaroides* that further add to the complexity of the synonymy. These are *"scalarioides,"* which seems to have originated with Reeve (1845) and *"scalariformis,"* an emendation by Locard. This same author had previously suggested in a footnote (1886, p. 165) "melius: *scalaformis,*" but apparently decided this was not "optimus" and so in 1892 (p. 101) employed the name *"M." scalariformis.*

As is typical of all Dermomurexes the type-species begins life with six varices. It ultimately changes to only three varices, but most individuals seen still possess six, five, or four varices, depending upon the growth-state. These six-varixed juveniles have been identified by authors as *"Murex" distinctus* (*e.g.*, Reeve, 1845, pl. 32, fig. 161; Philippi, 1836, pl. 11, fig. 32). For a comparison of the Recent species, its Pliocene ancestor *"Murex" arlus* de Gregorio, 1885, and the true *D. distinctus,* see pl. 5, figs. 5 and 8; and pl. 4, fig. 7. The differences between the Recent *D. scalaroides* and the Pliocene *D. arlus* are minimal, and the two may well be the same biologic species, but the older form seems to be consistently more inflated, with a body whorl that is relatively larger than the spire in contrast to the approximately equal-proportioned appearance of the Recent form.

A second name was proposed for the group by Cossmann, who to all appearances did not understand the nature of the species of *Aspella* or *Dermomurex*. *Aspella* Mörch, he stated (1903, p. 54), has six lamellar varices and hence he included *Poweria* (apparently unaware of *Dermomurex*) in synonymy with *Aspella* s.s., placing the genus in the subfamily Trophoninae. He noted that the genus differs from *Trophon* by its tropical rather than boreal distribution, and by having *only* six varices. His diagnosis was said to be based upon the species *"Trophon" engonatus* Dall, which is a *Dermomurex*. It would seem that his concept of the genus *Aspella* also came from Dall (1889), whose treatment of the aspelloids is discussed further in the Systematic portion of this paper.

In the same work, Cossmann (*ibid.*, p. 47) proposed a new subgenus of *Hadriania,* which he named *Hexachorda*. The name itself gives a clue to what Cossmann seemed to think was the distinguishing feature of this group, and he makes much of the varices being cord-like rather than lamellar or foliaceous. He named as type the French Miocene species *"Murex" tenellus* Mayer, 1869, which is another example of *Dermomurex*. However, it is probable that he was misled by Mayer's original illustration, which is a juvenile specimen of *"M." tenellus,* for the shell that Cossmann illustrates as *Hadriana (Hexachorda) tenella* (*ibid.*, pl. 2, fig. 14) is not *"M." tenellus* but is probably an example of *D. distinctus* (Cristofori and Jan). As he included the species *"Murex" cotteavi* Meunier in this group, *D. distinctus* is clearly what he had in mind for the type-species of the genus. The misidentification of *D. distinctus* as *"M." tenellus* is repeated in Cossmann and Peyrot (1923, pl. 12, figs. 48, 49) and in this instance there is no doubt about the identification of the figured specimen.

Had Cossmann named either *D. distinctus* or *D. cotteavi* as type for his new subgenus there would have been justification. These species are members of a subgroup that do have a morphologic distinctness, and it clearly is this group that he had in mind. By naming *"M." tenellus* as type, however, he created an unequivocal synonym of *Dermomurex* s.s., and it remained for Kuroda (1953) to propose the name *Takia* for the group.

The type lot of Mayer's *Murex tenellus* includes four specimens. In the original description (1869, p. 82) Mayer stated, "je n'en ai que trois examplaires," with the measurements of the type cited as "Long. 17, lat. 7 mill." The original label is still in the box and it can be seen that this label has been altered to read "4 ex." One of the specimens (figured here on pl. 2, fig. 1) measures 15.7 mm in height and is the one figured by Mayer. It is here designated as lectotype. However, there is a larger specimen that was added later (here figured on pl. 2, fig. 2). Mayer's original illustration was an apertural view only and the specimen appears to have six varices, but this can be seen to be a false impression by examining the dorsal view given here. The larger specimen removes any doubt as to the generic affinities of the species. It is a typical three-varixed *Dermomurex*.

In the New World a species similar to *D. tenellus* first appears in the late lower Miocene Chipola Formation of Florida. This new species *D. matercula,* is probably a direct ancestor to *D. pauperculus* (C. B. Adams), living in the western Atlantic, and also to two of the species of *Dermomurex* from the west coast of tropical America. Here the genus is flourishing and there are five species: *D.*

indentatus (Carpenter), *D. obeliscus* (A. Adams), *D. myrakeenae* (Emerson and D'Attilio), *D. cunninghamae* (Berry), and *D. bakeri* (Hertlein and Strong). The first three species have been the subject of a paper by Emerson and D'Attilio (1970) and are well figured there. From their illustrations it can be seen that *D. indentatus* is the Pacific "cognate" of *D. engonatus* (Dall) and *D. obeliscus* is the "cognate" of *D. pauperculus*. *D. myrakeenae* seems most closely related to the ancestral Oligocene *D. cookei* and is here referred to *D. (Takia); D. cunninghamae* is the type-species of the subgenus *Trialatella* Berry, 1964; *D. bakeri* is the type-species of *Gracilimurex* Thiele, 1929.

For the most part the Recent species of *Dermomurex* s.s. are confined to the New World. However, in the geologic record the genus has a much greater distribution. As noted above, *D. tenellus* is found the Miocene of southern Europe; and another similar form *"Murex" transsylvanicus* Hoernes and Auinger, 1885, from Lapugy, Hungary, is its contemporary in central Europe. In the Pliocene of Italy *D. tenellus* is replaced by *D. arlus* (de Gregorio), the ancestor of *D. scalaroides;* and in Australia there is a Pliocene form, *"Murex" crassiliratus* Tate, 1888. An Indo-Pacific species, *"Tritonalia" quilonica* Dey, 1962, was described from beds in southern India that are stated to be lower or middle Miocene in age (Subramanyan, 1964, pp. 59, 62). If the age is correct (and there is no statement as to basis for this age determination) then the history of the Dermomurexes as here established is subject to some rearrangement because this Indian species more nearly resembles the Florida Pliocene *D. engonatus* (Dall) than any other form. For now it must remain an enigma.

In the Recent fauna of the Indo-Pacific there is but a single species referred, with some hesitation to *Dermomurex* s.s. This is an apparently undescribed species, which is a somewhat atypical example of the line in that the aperture is totally smooth with no trace of the denticulations on the outer lip occurring in every other member of the genus. Except for this unusual form, there is but one species of *Dermomurex* s.s. outside of the New World, the type of the genus, which is from the Mediterranean. Two other species are Indo-Pacific in distribution and are here assigned one to the subgenus *Takia* and the second to *Viator*.

GRACILIMUREX: In the Gulf of California, western Mexico, there is a strange form that has been named as the type-species of the subgenus *Gracilimurex* Thiele, 1929 (as *"Murex" bicolor* Thiele, *non M. bicolor* Risso, 1826, *nec* Valenciennes, 1832, *nec* Cantraine, 1835). Originally described without locality, it is, without doubt, the same species subsequently named *Aspella bakeri* Hertlein and Strong, 1951. The taxonomic placement of this subgenus is uncertain as it seems to be intermediate between *Dermomurex* and *Aspella* s.s. There is a tendency toward bilateral flattening but the early whorls of the shell look more like those of *Dermomurex*. The spiral ornamentation is greatly reduced but seems also to be more akin to that of *Dermomurex* than to *Aspella* s.s., which usually is completely smooth or else has spiral rows of pustules. The color pattern of *"Aspella" bakeri,* which is a brown and white banding (hence the older name—*bicolor*) is strongly reminiscent of the west Mexican *A. pyramidalis,* but this may be convergence as the radulae of the two species are markedly dissimilar.

In the western Atlantic there is a form much like *"Aspella" bakeri* lacking, however, the marked color bands. This is the Recent species *"Aspella" elizabethae* McGinty, 1940. In the Pleistocene beds of southern Florida we find specimens of what would appear to be a form intermediate between *Dermomurex engonatus* (Dall) and *"Aspella" elizabethae*. It has the tendency toward the loss of varices and consequent bilateral flattening of *A. elizabethae* but has the strong spiral ornamentation of *D. engonatus*. Whether it is in fact the ancestor of *A. elizabethae* is not at all certain and the fossil history of *"Aspella" bakeri* is totally unknown, so for the time we can make no statements concerning the relationship between these various species. It may well be that the two Recent species represent parallel evolution and are not closely related but, according to Radwin (*in*

litt.), the radulae of the two are extremely close, indicating that they are common descendants of some as-yet unknown ancestor.

The weight of the evidence suggests that the group is more closely allied with *Dermomurex* than with *Aspella* s.s., and so it is considered as a subgenus of *Dermomurex* herein.

TRIALATELLA: The fourth of the above-mentioned eastern Pacific species of *Dermomurex, D. cunninghamae,* was named as the type of a new genus *Trialatella* by Berry (1964) but the type species (holotype figured here, pl. 4, fig. 4) shows differences that are subgeneric at best. The group is characterized by having three greatly expanded wing-like varices in the adult stage. The line has its ancestry in another Chipola species, *D. farleyensis,* n. sp. Although not previously recognized in the western Atlantic the subgenus is still present, with a species that is very near the west Mexican *D. cunninghamae.* This form is thought to be the species named *"Murex" abyssicola* Crosse, but further collecting may show that two species occur in the Caribbean.

TAKIA: The earliest species of *Dermomurex, D. cookei,* n. sp., and *D. cotteavi* (Meunier), from the Oligocene of Mississippi and France, respectively, are both characterized by the retention of six varices through their entire growth-span. In addition, the varices are rounded and cord-like, being only indistinctly set off from the remainder of the shell. The line persists in the Old World with the species *"Murex" distinctus* Cristofori and Jan, 1832, which is widespread in the Miocene and Pliocene of the European area. It has been reported from the Miocene of Austria (Hörnes, 1856, pl. 25, fig. 7, as *Murex distinctus*), Poland (Friedberg, 1912, pl. 11, fig. 16, as *Aspella anceps*!), Italy (Montanaro, 1935, pl. 4, fig. 1, as *A. scalarioides* var. *distincta* from the Miocene, and D'Ancona, 1871, pl. 2, fig. 4, as *M. distinctus,* from the Pliocene), and France (Glibert, 1952, pl. 6, fig. 7, as *A. scalarioides*). The French Miocene species *"Murex" cancellarioides* Grateloup, 1833, (and its emendation *M. cancellariiformis* Mayer) is the same. In the Miocene of Java *"Murex" acuticostatus* Wanner and Hahn, 1935, *(non M. acuticostatus* Gümbel, an *Ocinebrina*) is extremely close to *D. distinctus* and may well be the same species. In the middle Miocene (Balcombian) of Australia there is another species, *"Murex" pachystirus* Tate, 1888, that is still very much like the Oligocene *D. cotteavi,* its presumed ancestor. Probably this is the species that gave rise to the Recent *D. infrons* Vokes (a new name proposed in 1974 for the preoccupied *"Murex" inermis* Sowerby), type of *Takia* Kuroda, 1953. Most of the examples of *D. infrons* have six varices in the adult (see pl. 5, fig. 1) and it looks rather like the Mio-Pliocene *D. distinctus* (figured here pl. 5, fig. 5). However, specimens have been collected that have lost every other varix on the last whorl, which suggests that here is another branch that is shifting, somewhat belatedly, from six to three varices.

In the New World the species *D. myrakeenae* (Emerson and D'Attilio) still retains six varices normally, although some specimens do show a tendency to lose one or more of the last ones (see pl. 5, fig. 7). Morphologically the shell is still much like the Oligocene *D. cookei,* and one can only assume that there is a long "missing link" connecting the two species. No other known forms in the fossil record of the New World are at all close to these two.

VIATOR: In the vicinity of northwestern Australia there is a second Indo-Pacific species, only recently described, *D. (Viator) antonius* Vokes (1974, p. 4). This elegant species is the sole descendant of a line that branched off the original *Dermomurex* stock early in the history of the group. In the early lower Miocene (Aquitanian) of the eastern United States there is a species described as *"Murex (Panamurex) gilletteorum"* by the writer. This name proved to be a synonym of *"Murex" sexangula* Dall, 1915, but under either name it is the first member of an unusual line of the aspelloids. This early Miocene form is assumed also to have given rise to a bizarre side group of species, two in the Chipola Formation of Florida and a third in the beds of the same age in Italy and France. But in the middle Miocene (Balcombian) of Australia there appears

another species, *"Murex" asteriscus* Tate, 1888, that can only be interpreted as a direct descendant of the early Miocene *D. sexangulus*. The mechanism of this migration is a complete enigma, but in light of present knowledge such migration is unavoidable. There are no other similar species until the appearance of the Recent *D. antonius*. Without the presence of this modern form the affinities of the fossil species would still be somewhat puzzling, as they have been to the writer previously. But the Recent species with its heavy coat of intritacalx (see pl. 6, fig. 4) immediately shows the placement within the aspelloids. Fossil specimens rarely have very much intritacalx preserved and it is mainly by analogy with the Recent descendants that we can determine how the fossils must have appeared in life. A comparison of pl. 6, figs. 3 and 5, suggests what the older forms of *Viator* must have looked like.

At first glance one might wonder at the necessity for the erection of a subgenus to accommodate these few species of *Dermomurex*. The subgeneric name *Takia* very nearly could be applied to them. However, when one examines the type-species (see pl. 5, fig. 1) it can be seen that in actuality *D. infrons* is more like the ancestral *D. cookei* and *D. cotteavi* than it is like the species here referred to as *Viator*. In *Viator* there is an elongation of the anterior canal and a comparable shortening of the spire. In the ancestral Oligocene species the distance from the posterior edge of the aperture to the apex is almost exactly one-half the total height of the shell. The same ratio is still present in *D. infrons*. However, in *D. antonius* it is about one-third, and in *D. asteriscus* it is between one-third and one-half (four-tenths). The spiral ornamentation is also much more pronounced in *Viator*, and the anterior canal is straight rather than curved.

III. ACKNOWLEDGMENTS

As noted in the Introduction this study necessitated more than the usual amount of borrowing. The writer would like to express her appreciation to all those persons who provided specimens, photographs, information, and all manner of assistance. These include: Joseph Rosewater and Porter M. Kier, U.S. National Museum; R. Tucker Abbott, then at the Academy of Natural Sciences, Philadelphia; Kenneth J. Boss, Museum of Comparative Zoology, Harvard University; William K. Emerson, American Museum of Natural History; C. Wyatt Durham and Joseph H. Peck, Jr., University of California, Berkeley; Kenneth Thomas, British Museum (Natural History); William G. Lyons, Marine Research Laboratory, St. Petersburg, Florida; Barry Wilson, Western Australian Museum, Perth, Western Australia; John W. Tunnell, Jr., Texas A. and M. University; F. Stearns MacNeil, Ft. Myers, Florida; John Phillips, Santa Barbara, California; Evelyn Garver, Lake Worth, Florida; Mr. and Mrs. Robert C. Hoerle, West Palm Beach, Florida; Evelyn Bradley, Bradenton, Florida; Eugenia Wright, Sanibel, Florida; Lorna Marrow, Hampton, Victoria, Australia; and Dario Franchini, Mantova, Italy.

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IV. SYSTEMATIC DESCRIPTIONS

Phylum MOLLUSCA
Class GASTROPODA
Subclass PROSOBRANCHIA
Order NEOGASTROPODA
Suborder STENOGLOSSA
Superfamily MURICACEA
Family MURICIDAE
Subfamily MURICINAE
Genus ASPELLA Mörch, 1877

Aspella MÖRCH, 1877, Malak. Blatter, v. 24, p. 24.

Type-species: *Ranella anceps* Lamarck, by monotypy.

ASPELLA SENEX Dall

Plate 1, figs. 1–4, 7

[?] *Aspella anceps* (Lamarck). DALL, 1889, Harvard Mus. Comp. Zool., Bull., v. 18, p. 207. [Based on previous authors' reports only].

Aspella hastula (Reeve). DALL, 1889, Harvard Mus. Comp. Zool., Bull., v. 18, p. 207 (*not* of Reeve).

Aspella senex DALL, 1903, Wagner Free Inst. Sci., Trans., v. 3, pt. 6, pl. 60, fig. 14 (not in text).

Aspella senex Dall. SCHUCHERT *et al.,* 1905, U.S. Natl. Mus., Bull. 53, pt. 1, p. 67.

Aspella hastula (Reeve). JOHNSON, 1934, Boston Soc. Nat. Hist., Proc., v. 40, no. 1, p. 116 (*not* of Reeve).

Aspella senex Dall. OLSSON and HARBISON, 1953, Acad. Nat. Sci. Phila., Mon. 8, p. 250, pl. 39, fig. 8.

Aspella anceps (Lamarck). WARMKE and ABBOTT, 1962. Caribbean Seashells, p. 108, pl. 19, fig. C (*not* of Lamarck).

Aspella senex Dall. S. E. HOERLE, 1970, Tulane Stud. Geol. Paleont., v. 8, no. 2, p. 64.

[?] *Aspella anceps* (Lamarck). RIOS, 1970, Coastal Brazilian Seashells, p. 83.

[Aspella] (Aspella) senax [sic] Dall. E. H. VOKES, 1971, Bulls. Amer. Paleontology, v. 61, no. 268, p. 97.

Aspella anceps (Lamarck). PORTER and WOLFE, 1971, Jour. de Conchyl., v. 109, p. 96, 104 (*not* of Lamarck).

Diagnosis: "Shell small, subfusiform, the spire 1½ to 2 times the length of the aperture, strongly compressed dorso-ventrally and sculptured with bowed, axial riblets. Aperture subelliptical, the forward part narrowed and produced into a medium-length, straight, anterior canal. Peristome nearly continuous, with a slightly raised rim, the outer lip thickened by the last varix, the inner side of the lip smooth or crenulate. Axials about 6, 2 each on the dorsal and ventral sides, the other 2 on the lateral sides being somewhat stronger and forming varices which mark the position of the aperture at earlier stages of growth. Surface between the axials is smooth or with an earthy texture, sometimes with faint spirals." (Olsson and Harbison, 1953)

Dimensions of holotype: height 9.5 mm, diameter 4.0 mm.

Holotype: USNM 163959.

Type locality: Shell Creek, Cleveland County, Florida (= TU 539).

Occurrence: Pinecrest beds, (?) early and middle Pliocene; Caloosahatchee Formation, late Pliocene; unnamed post-Caloosahatchee formation, Pleistocene; Florida. Recent, from Cape Fear, North Carolina, to Ft. Walton, Florida. West Indies and Yucatán Peninsula.*

Figured specimens: Fig. 1, USNM 739566; height 14.0 mm, diameter 8.0 mm; "Hourglass" Station L, about 85 miles off Ft. Myers, Florida, 27 fathoms. Fig. 2, USNM 647439; height 14.6 mm, diameter 6.4 mm; locality TU 759. Fig. 3, USNM 647440; height 12.3 mm, diameter 5.6 mm; locality TU 726. Fig. 4, USNM 647441; height 7.0 mm, diameter 3.5 mm; locality TU 726. Fig. 7, USNM 93510; height 9.7 mm, diameter 4.5 mm; *Blake* Station 2617, 25 miles off Cape Fear, North Carolina, 14 fathoms. Other occurrences: TU locality nos. 201, 202, 203, 529, 536, 727, 729, 767, 768, 803, 1000, R-99, R-263, R-283.

Discussion: As noted in the Introduction, the species *Aspella anceps* has been poorly understood because Lamarck cited neither locality nor figure. The species of *Aspella* s.s. that occurs not uncommonly in the western Atlantic has been identified as *A. anceps* by several authors, but the American shell is, in reality, the equivalent of the other Indo-Pacific species, *A. producta* (Pease).

The western Atlantic species first appears in the Pliocene Pinecrest beds of southern Florida. However, it is rare here, being represented in the Tulane Collections by a single specimen from TU 729 and another one from the latest Pinecrest beds at TU 1000 (in the collection of Mrs. Evelyn Bradley, of Bradenton, Florida). Heretofore the Pinecrest beds have been correlated with other formations that bear planktonic foraminifera

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*The writer recently has learned that *Aspella senex* was taken live at Enmedio Reef, just off Veracruz, Mexico, in the western Gulf of Mexico, by J.W. Tunnell, Jr., Texas A.& M. University *(in litt.)*. This represents a considerable extension of range. Along with *Aspella senex* were several other muricine species usually associated with the Caribbean reef faunas, including *Dermomurex pauperculus,* another extension of range.

indicating an age of lower Pliocene (Zone N. 19) (see Akers, 1972) but more recent work on calcareous nannofossils found at locality TU 1000, Sarasota, Florida, gives an age of middle Pliocene (Zone N. 20) (Akers, 1974). Inasmuch as the lower and upper parts of the Pinecrest unit have certain molluscan differences it seems probable that the lower portion of the Pinecrest is, in fact, lower Pliocene and the upper part (that usually referred to as the "Brighton facies") is middle Pliocene. However, until more definite evidence is available detailed age assignments for various localities are conjectural.

In the later Pliocene beds of the Caloosahatchee Formation *A. senex* is somewhat less rare but it is never a common shell. It persists with approximately the same degree of rarity through the Pleistocene "Glades" fauna and is still living in the Gulf of Mexico and the Caribbean today. Modern depth records range from 14 to 30 fathoms. The apparent rarity of the species in the fossil fauna is probably due to its small size, as Warmke and Abbott (1962, p. 108) note that the Recent form is "fairly common in drift sand and shallow dredgings."

At first appearance the modern form does not look as though it is the same species as the fossil representatives. This is due to the peculiar nature of the intritacalx, which forms extensions of the varices in the living animal. In the fossil condition the intritacalx is usually lacking and the shell appears to be narrower, with less extended varices. Comparison of a worn Recent specimen with a fossil one, however, demonstrates the similarity. (Compare pl. 1, fig. 2, a fossil, and fig. 7, a worn Recent specimen).

The only person who has ever done any work at all on this group in the western Atlantic was Dall, who seemingly did not understand the strange nature of the aspelloids. His treatment of the *Dermomurex* line is even more confused than that of *Aspella* s.s., and his concept of *Aspella anceps* is unfathomable. In the *Blake* Report (1889, p. 207) he identified the western Atlantic species of *Aspella* s.s. as *Aspella hastula* Reeve, which he stated "has 3-5 varices to the whorl; *A. anceps* always six. The revolving lines are less elevated than is usual with *A. anceps,* and never nodulated, as is often the case with the latter." The specimen that he cited as *A. hastula* is USNM 93510 (here figured, pl. 1, fig. 7), and it is a worn example of *A. senex,* lacking the white intritacalx, which gives it a flesh color, not "chestnut-brown" as Dall stated, unless it has faded greatly over the last 80 years. His description of *A. anceps* sounds more like *Dermomurex* than *Aspella* s.s. but he discussed the species of *Dermomurex* in some detail, although he did not use the name, considering them as members of *Aspella* s.l. His treatment of this group will be covered under *D. (Dermomurex) pauperculus.*

Genus DERMOMUREX Monterosato, 1890

Poweria MONTEROSATO, 1884, Nomen. Conch. Medit., p. 113. (*Non Poweria* Bonaparte, 1840).

Type species: *Murex scalarinus* Bivona-Bernardi, by original designation *[Murex scalarinus* Bivona-Bernardi, 1832, = *Murex scalaroides* Blainville, 1829].

Dermomurex MONTEROSATO, 1890, Natural. Sicil., v. 9, p. 181. New name for *Poweria* Monterosato *non* Bonaparte.

Hexachorda COSSMANN, 1903, Essais Paléoconch. Comp., v. 5, p. 47.

Type species: *Murex tenellus* Mayer, by original designation.

Subgenus DERMOMUREX s.s.

DERMOMUREX (DERMOMUREX) MATERCULA* E. H. Vokes, n. sp.

Plate 2, fig. 3

Diagnosis: Protoconch of one and one-half large, bulbous whorls, with seven post-nuclear whorls in adult specimen. Axial ornamentation beginning on first post-nuclear whorl with six crescentic varices that overlap onto the protoconch. Each succeeding whorl with six strap-like varices, until about the fifth post-nuclear whorl where certain of these become greatly reduced so that they are little more than inter-varical nodes, their former existence being demonstrated mainly by the presence of a small

*The latin word *matercula,* "little mother," is a noun and does not agree in termination with the masculine *Dermomurex.*

buttress at the suture and a small flange at the anterior canal. Spiral ornamentation consisting of two to four weak cords on the early whorls and about eight on the body-whorl, almost invisible except where they cross the varices, with deep pits formed between the cords. Entire shell, except for the protoconch, covered with a heavy intritacalx, but larger specimens usually decorticated and this coating best seen on juveniles. Intritacalx almost smooth when fresh, but beneath the surface a system of fine tunnel-like structures may be seen at broken edges of the intritacalx; these appearing when slightly worn as fine spiral grooves covering the shell surface. Suture greatly appressed and situated toward the anterior end of the whorl, so giving a marked convexity to each whorl; body-whorl almost twice the height of the spire. Aperture elliptical, outer lip slightly crenulated at the spiral cords, with a small raised rim; very faint denticles may appear on the inside of the outer lip. Terminal varix rounded, with slight nodes where the spiral cords cross, a small flange developed on the anterior portion where the

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PLATE 1

Figures Page

1–4,7. *Aspella senex* Dall 132

1. (X 3) USNM 739566; height 14.0 mm, diameter 8.0 mm.
   Locality: "Hourglass" Station L, off Fort Myers, Florida, 27 fathoms. Recent.
2. (X 3) USNM 647439; height 14.6 mm, diameter 6.4 mm.
   Locality: TU 759. Unnamed post–Caloosahatchee formation, Florida; early Pleistocene.
3. (X 3) USNM 647440; height 12.3 mm, diameter 5.6 mm.
   Locality: TU 726. Caloosahatchee Formation, Florida; late Pliocene.
4. (X 8) USNM 647441; height 7.0 mm, diameter 3.5 mm.
   Locality TU 726. Caloosahatchee Formation, Florida; late Pliocene.
7. (X 4) USNM 93510–*"Aspella hastula"* of Dall (1889, p. 207); height 9.7 mm, diameter 4.5 mm.
   Locality: *Blake* Station 2617, off Cape Fear, North Carolina, 14 fathoms. Recent.

5,6. *Aspella anceps* (Lamarck) (X 3) 124

5. MCZ 209445; height 10.7 mm, diameter 4.0 mm.
   Locality: Port Alfred, South Africa. Recent.
6. Marrow Coll.; height 12.8 mm, diameter 5.8 mm.
   Locality: Wooli, New South Wales, Australia. Recent.

8. *Aspella hastula* (Reeve) (X 3) 126
   USNM 739567; height 12.4 mm, diameter 6.0 mm.
   Locality: Galápagos Islands. Recent.

9. *Aspella* sp. (X 3) 126
   USNM 739568; height 13.5 mm, diameter 7.0 mm.
   Locality: TU R–166, Barra de Navidad, Jalisco, Mexico. Recent.

10–13. *Aspella pyramidalis* (Broderip) 124
   Locality: TU R–166, Barra de Navidad, Jalisco, Mexico. Recent.

10. (X 3) USNM 739569; height 13.5 mm, diameter 5.7 mm. With intritacalx present.
11. (X 3) USNM 739569; height 12.7 mm, diameter 5.5 mm. With intritacalx removed, showing underlying color pattern.
12. (X 8) USNM 739569; height 7.4 mm, diameter 3.9 mm. Juvenile specimen.
13. (X 3) USNM 739569; height 15.0 mm, diameter 6.5 mm. Whitened to show details of ornamentation.

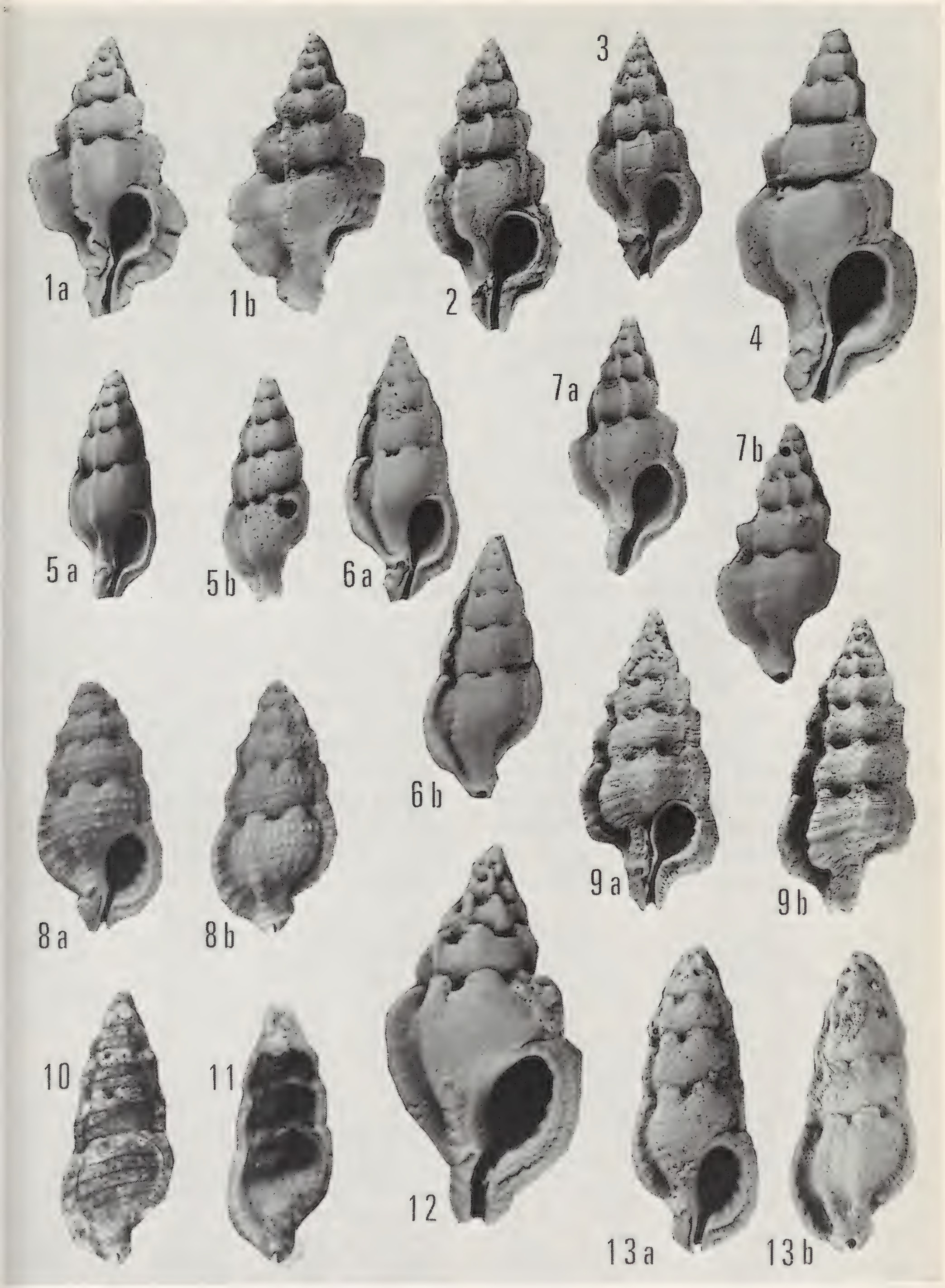


PLATE 1

varix curves into the basal constriction forming the anterior canal. Inner lip smooth, appressed posteriorly, standing free at anterior end, partially covering the relatively large umbilical fasciole. Anterior canal short, open by a slit, strongly recurved at the distal end toward the dorsum.

Dimensions of holotype: height 16.2 mm, diameter 8.5 mm.

Holotype: USNM 647442.

Type locality: TU 830, Ten Mile Creek, at power-line crossing about one mile west of Chipola River (SE¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.

Occurrence: Chipola Formation, late lower Miocene, Florida.

Figured specimen: USNM 647442 (holotype). Other occurrences: TU locality nos. 547, 548, 555, 825, 827, 998.

Discussion: This new species, which is almost certainly the direct ancestor of the Recent *D. (D.) pauperculus,* is rare in the Chipola Formation of northwestern Florida. The type lot contains, in addition to the holotype, only eight smaller paratypes. Three of these were taken at TU 548, on the Chipola River, all other localities listed above being represented by a single specimen. In contrast, the second species of *Dermomurex* described from the Chipola Formation is much less rare, although scarcely what would be called common. The distribution of the two forms is distinct, with *D. (Trialatella) farleyensis* almost totally confined to localities on Farley Creek. *D. (D.) matercula* is less restricted, with a small representation from each area: Chipola River, Ten Mile Creek, and Farley Creek.

D. matercula may be readily distinguished from *D. farleyensis,* as the body-whorl tends to be more rounded and the shell is inflated at the anterior end, rather than being constricted toward the siphonal canal; the spiral ornamentation of *D. matercula* is much more conspicuous than that of *D. farleyensis,* which is almost non-existent. From its modern descendant, *D. pauperculus,* it may be distinguished by the much less elongate shell; pl. 2, fig. 7, is a worn example of *D. pauperculus* of the same number of whorls as the holotype of *D. matercula* and comparison shows the difference in outline. In addition, the spiral ornamentation is much stronger in the younger species.

It seems probable that the French middle Miocene species *D. tenellus* (Mayer) is also a descendant of *D. matercula.* While the European Oligocene *D. (Takia) cotteavi* (Meunier) clearly gave rise to *D. (Takia) distinctus* (Cristofori and Jan), *D. tenellus* is so unlike either of these species and so like the American *D. matercula,* there can be little argument. As the writer has noted before, the fauna of the French Aquitaine Basin is remarkably similar to that of the Chipola, and there almost has to have been interchange in both directions (see Vokes, 1973, p. 97). It should be noted that the specimen Cossmann and Peyrot (1923, pl. 12, figs. 48-49) figure as a Burdigalian example of *"Hexachorda tenella"* is actually a specimen of *D. (T.) distinctus.*

DERMOMUREX (DERMOMUREX) ENGONATUS (Dall)

Plate 3, figs. 5, 6

Trophon (Aspella) engonatus DALL, 1892, Wagner Free Inst. Sci., Trans., v. 3, pt. 2, p. 243, pl. 13, fig. 6a.

Aspella engonata (Dall). DALL, 1903, Wagner Free Inst. Sci., Trans., v. 3, pt. 6, p. 1607.

[Aspella (Aspella)], engonatus (Dall). COSSMANN, 1903, Essais Paleoconch. Comp., v. 5, p. 55, text fig. 4.

Trophon (Aspella) engonatus Dall. SCHUCHERT, *et. al.,* 1905, U. S. Natl. Mus., Bull. 53, pt. 1, p. 670.

Aspella scalarioides (Blainville). MAURY, 1917, Bulls. Amer. Paleontology, v. 5, no. 29, p. 268 (104), pl. 43 (17), fig. 11 (*not* of Blainville).

Aspella (Aspella) engonata (Dall). OLSSON and HARBISON, 1953, Acad. Nat. Sci. Phila., Mon. 8, p. 251, pl. 39, fig. 5.

[Aspella] (Dermomurex) engonatus (Dall). E. H. VOKES, 1971, Bulls. Amer. Paleontology, v. 61, no. 268, p. 45.

Diagnosis: "Shell elevated, with prominent sculpture and eight whorls; nucleus small, smooth, of two and a quarter whorls; remaining whorls each with three principal and three minor varices, which are thin, sharp and spinose at the intersection of the spiral ribs, especially at the shoulder; whole surface covered with a thin limy coat, evenly and finely spirally striate, but this coating is usually partly worn off, being very perishable; other spiral sculpture of three (on the last whorl 6) sharp, narrow, elevated spiral riblets which overrun the varices, and (especially on the major varices) tend to form spines at the intersection; the spiral rib at the shoulder is especially prominent and tends to

turriculate the whorls; whorls full, rounded under the sculpture; aperture ovate; canal long, open, narrow, much recurved; outer lip with a few coarse lirae within the adult." (Dall, 1892)

Dimensions of lectotype: height 28 mm, diameter 12 mm.

Lectotype: USNM 113273.

Type locality: Shell Creek, Cleveland County, Florida (=TU 539).

Occurrence: Pinecrest beds, early and middle Pliocene; Caloosahatchee Formation, late Pliocene; unnamed post-Caloosahatchee formation, Pleistocene; Florida. Gurabo Formation, Dominican Republic; (?) Miocene. (?) Tuberá Group, Colombia; Pliocene.

Figured specimens: Fig. 5, USNM 647444; height 26.4 mm, diameter 11.0 mm; locality TU 797. Fig. 6, USNM 647445; height 18.2, diameter 8.8 mm; locality TU 768. Other occurrences: TU locality nos. 202, 203, 520, 529, 536, 539b, 579, 726, 729, 745, 767, 768, 769, 770, 797, 933, 974, 975, 978, 991, 1000, 1023.

Discussion: D. engonatus is the commonest fossil species of *Dermomurex,* being relatively widespread in the Pliocene beds of south Florida. It is equally well represented in both the Pinecrest beds and the Caloosahatchee Formation, but to the writer's knowledge there is only a single unequivocal specimen from the Pleistocene "Glades" fauna. The species is found at a number of localities where both the Caloosahatchee and the "Glades" occur together, but only TU locality 978, South Bay, Florida, is a pure "Glades" locality. At two other unmixed "Glades" localities (TU 759 and 803) a different form, which is intermediate between *D. engonatus* and the Recent *D. elizabethae,* occurs. This variant has a tendency toward the loss of the third major varix and shows a bilateral flattening that is more akin to *D. elizabethae,* although the spiral ornamentation is stronger, as in *D. engonatus* (see pl. 3, figs. 3, 4).

In addition to the Florida occurrences this species has been figured from the Gurabo Formation of Santo Domingo by Maury as *"Aspella scalarioides."* Maury noted (1917, p. 268) that "Dr. Dall very kindly examined our specimen and decided it was identical with the recent species living in the Antilles and the Mediterranean." Dall's Recent *"scalarioides"* included *D. pauperculus* of the Antilles and *D. scalaroides* of the Mediterranean; Maury's figured specimen is neither of these but is very clearly the same as *D. engonatus.* In the collections from the Museum of Paleontology, Berkeley, there is another specimen of *D. engonatus* from Punta Puá, near Cartagena, Dept. of Bolivár, Colombia. It was collected by T. J. Etherington, and was indicated as being from a "Miocene fauna in 2 foot band above the coral limestone," presumed to be in the Tuberá Group. At the same locality there are specimens of *Murex olssoni* Vokes, originally named from the Recent and from beds near Limon, Costa Rica, which were then thought to be upper Miocene in age, the "upper Gatun" of Olsson. These beds are now known to be the Moín Formation, of early Pleistocene age, correlating with the "Glades" fauna of south Florida, and *Murex olssoni* is believed to be confined to the Pliocene and later formations. Thus the Tuberá occurrence of *D. engonatus* is probably Pliocene. The age of the beds in Santo Domingo has always been considered to be middle Miocene; however, recent work on planktonic foraminifera is shifting many of the western Atlantic formations into a position stratigraphically higher than previously thought, and there is considerable evidence that the Santo Domingo beds may also be, at least in part, Pliocene in age.

In terms of chronology *D. pauperculus* should be the modern descendant of *D. engonatus,* but the two forms are sufficiently dissimilar as to cast doubt on this relationship. The Recent species lives among the rocks of the intertidal zone and this is almost the worst environment for fossil preservation. *D. engonatus* is the only fossil *Dermomurex* species that may be said to be "common" and this is probably because of its having lived in water of a slightly greater depth. Unfortunately nothing is known of the habitat of the Recent West Coast *D. indentatus* (Carpenter), which unquestionably is the modern descendant of *D. engonatus,* but presumably if it were intertidal it would not be so rare in collections. The writer suspects that there is a long unbroken line of very shallow water species extending from the Chipola *D. matercula* to the Recent *D. pauperculus,* which simply have not been taken as fossils, and the *D. engonatus-D. indentatus* line is a distinct side-branch.

The Recent *D. indentatus* is sufficiently close to *D. engonatus* that Olsson and Harbison said (1953, p. 251): "That *engonata* occurs Recent along the Pacific coast of Panama and Central America is established by specimens in the U. S. National Museum from Panama City, which are indistinguishable in every way from the Florida shells." The two forms are close but not quite that close, and they are distinguishable by the relatively higher spire and straight-sided body whorl of *D. engonatus*. *D. indentatus* is diamond-shaped, with the shell distinctly extended at the periphery, which is, however, somewhat above the midline of the shell. The periphery of *D. engonatus* is indistinct, but is located almost exactly on the midline, giving the shell a more elongated appearance.

There is another name that has been cited as a western Atlantic species of *Dermomurex* –*"Murex" alabastrum* A. Adam, 1864 *(M. adamsii* Kobelt is an unnecessary new name for *M. alabastrum* Adams *non M. alabaster* Reeve). If this species were in fact from the western Atlantic it would be the undeniable descendant of *D. engonatus*. Unfortunately no examples comparable to it have ever been taken in the waters of the western Atlantic and, although described as coming from Martinique, the species is almost certainly the West Mexican *D. indentatus*. The illustration shows a small rounded aperture exactly like that of *D. indentatus*. The type specimen of *"Murex" alabastrum*, although originally in the Brit. Mus. (Nat. Hist.), is apparently lost (K. Thomas, *in litt.*) and so no photographic comparison is possible at this time.

In his original description Dall cited the measurements of his species as "Alt. 28 mm" but the figured specimen is cited as "22 mm." Schuchert *et. al* (1905, p. 670) listed USNM 113273 as the number of the "cotypes;" therefore, the specimen measuring 28 mm in height is here designated as the lectotype and the 22 mm figured specimen is considered a paralectotype.

DERMOMUREX (DERMOMUREX) PAUPERCULUS (C. B. Adams)

Plate 2, figs. 4–7

Murex pauperculus C. B. ADAMS, 1850, Contributions to Conchology, no. 4, p. 60.
Triton cantrainei RECLUZ, 1853, Jour. de Conchyl., v. 4, p. 246, pl. 8, fig. 10.

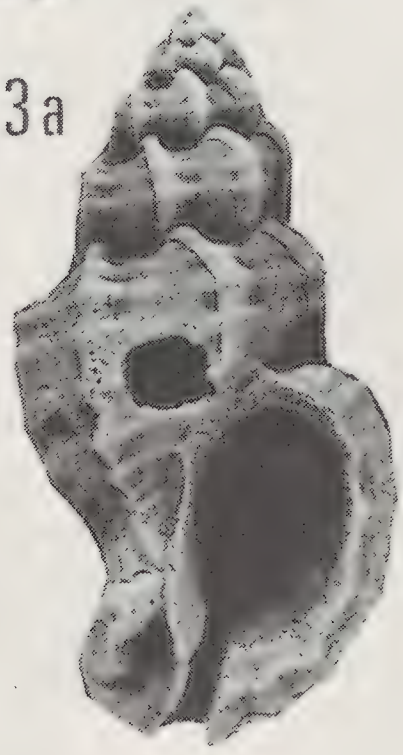
PLATE 2

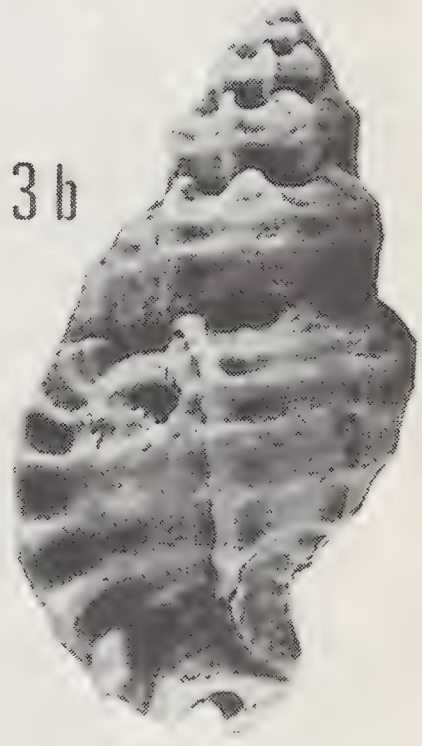
Figures — Page

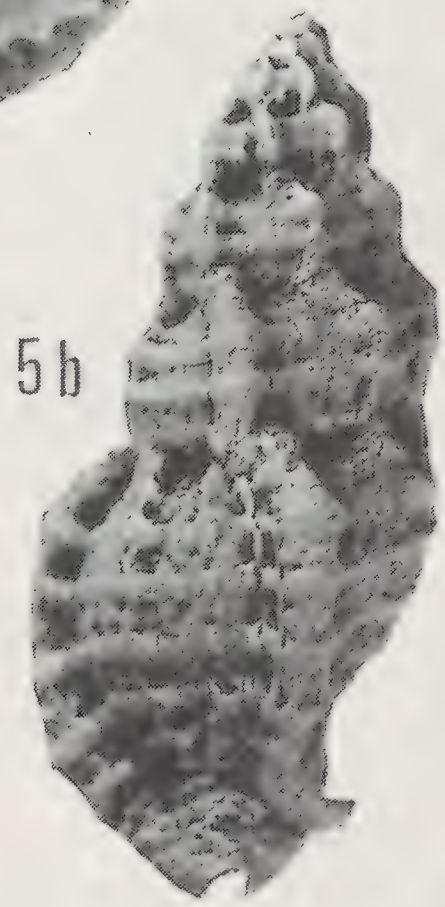
1,2. *Dermomurex (Dermomurex) tenellus* (Mayer) (X 3) 128
Locality: Pont-Levoy, near Blois, France. Helvetian Stage, middle Miocene.
1. Basel H 16677 (lectotype); height 15.7 mm, diameter 7.2 mm.
2. Basel H 16678 (idiotype); height 20.8 mm, diameter 11.0 mm.

3. *Dermomurex (Dermomurex) matercula* E.H. Vokes, n. sp. (X 3) 133
USNM 647442 (holotype); height 16.2 mm, diameter 8.5 mm.
Locality: TU 830. Chipola Formation, Florida; late lower Miocene.

4–7. *Dermomurex (Dermomurex) pauperculus* (C.B. Adams) 138
4. (X 3) USNM 739573; height 11.4 mm, diameter 6.4 mm.
Locality: TU R–68, Cayos Arcos, Mexico. Recent.
5. (X 2) MCZ 125072; height 30.0 mm, diameter 14.8 mm.
6. (X 2) MCZ 125072a; height 24.2 mm, diameter 12.0 mm.
Locality for both: Causeway, Biscayne Bay, Miami, Florida. Recent.
7. (X 3) USNM 739570; height 20.3 mm, diameter 10.0 mm.
Locality: TU R-94, Duarte Cays, north of Porto Bello, Panamá. Recent.







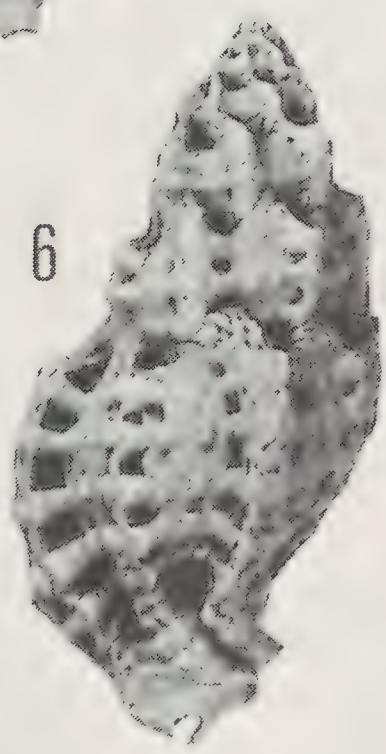


PLATE 2

Murex alveatus Kiener. TRYON, 1880, Man. Conch., v. 2, p. 128, pl. 38, fig. 264 *(Triton cantrainei)* (in part only, *not* of Kiener).

Aspella scalarioides var. *paupercula* (C. B. Adams). DALL, 1889, Harvard Mus. Comp. Zool, Bull., v. 18, p. 208.

Aspella scalarioides var. *obeliscus* (A. Adams). DALL, 1889, Harvard Mus. Comp. Zool., Bull., v. 18, p. 208 (*not* of Adams).

Aspella scalaroides (Blainville). DALL and SIMPSON, 1902, U. S. Fish Comm. Bull., v. 20, p. 410 (*not* of Blainville).

[Aspella] pauperculus (C. B. Adams). CLENCH and TURNER, 1950, Harvard Occas. Papers Moll., v. 1, no. 15, p. 323, pl. 39, fig. 16 (lectotype).

Aspella scalaroides obeliscus (A. Adams). M. SMITH, 1953, Illus Cat. Recent Species Rock Shells, p. 18, pl. 14, fig. 3 (*not* of Adams).

Aspella scalaroides paupercula (C. B. Adams). M. SMITH, 1953, Illus. Cat. Recent Species Rock Shells, p. 18, pl. 14, fig. 2.

Aspella paupercula (C. B. Adams). ABBOTT, 1958, Acad. Nat. Sci. Phila., Mon. 11, p. 62, pl. 1, fig. m.

Aspella paupercula (C. B. Adams). NOWELL-USTICKE, 1959, Check List Marine Shells St. Croix, p. 63.

Aspella paupercula (C. B. Adams). WARMKE and ABBOTT, 1962, Caribbean Seashells, p. 108, pl. 19, fig. d.

Aspella varians NOWELL-USTICKE, 1969, Supplementary Listing New Shells, p. 12; 1971, *ibid.* (revised ed.) p. 12, placed in synonymy with *Aspella cantrainei* Recluz.

[Aspella] (Dermomurex) pauperculus (C. B. Adams). E. H. VOKES, 1971, Bulls. Amer. Paleontology, v. 61, no. 268, p. 79.

Aspella paupercula (C. B. Adams). MORRIS, 1973, Field Guide to Shells . . . Third Edition (W. J. Clench, Ed.), p. 194, pl. 52, fig. 16.

Diagnosis: "Shell elongated, obliquely subfusiform: whitish, within the aperture yellowish: with three not very stout varices on each whorl, and slender intermediary varicoid ridges; with a few distant spiral ridges, the intersections being nodulous: apex subacute: spire with the outlines a little convex: whorls six, quite convex, with a deep suture: aperture elliptical: canal short, rather wide and recurved." (Adams, 1850)

Dimensions of lectotype: height 15.9 mm, diameter 7.8 mm.

Lectotype: Harvard MCZ 156124 (designated by Clench and Turner, 1950, p. 382).

Type locality: Jamaica.

Occurrence: Moín Formation, early Pleistocene; Costa Rica. Recent, western Atlantic from Florida to Lesser Antilles, and east coast of Central America from Mexico to Panamá.*

Figured specimens: Fig. 4, USNM 739573; height 11.4 mm, diameter 6.8 mm; locality TU R-68. Fig. 5, MCZ 125072; height 30.0 mm, diameter 14.8 mm; Biscayne Bay, Miami, Florida, on rocks. Fig. 6, MCZ 125072a; height 24.2 mm, diameter 12.0 mm; locality same as fig. 5. Fig. 7, USNM 739570; height 20.3 mm, diameter 10.0 mm; locality TU R-94. Other occurrences: TU locality nos. 954, R-44, R-181, R-269.

Discussion: Although *D. pauperculus* is by far the most common *Dermomurex* in the western Atlantic, as can be seen from the synonymy given above, it has been a long time in being recognized for what it is. The initial confusion may have been caused by Sowerby, who in the *Thesaurus Conchyliorum* (1879, pl. 23, fig. 233), gave a locality of "Isl. St. Thomas" for *"Murex" obeliscus* A. Adams, a species that had been described without locality. Tryon, the following year (1880, p. 128), combined *"M." pauperculus, "M." obeliscus,* and *"Triton" cantrainei,* all under the name *"M." alveatus* Kiener, a species that has only a superficial resemblance to the species of *Dermomurex.* While *"Triton" cantrainei* is undoubtedly a synonym of *D. pauperculus,* the other species *"M." obeliscus* A. Adams is not but, as has been shown recently by Emerson and D'Attilio (1970, p. 91), is a similar species from the west coast of tropical America.

Dall (1889, p. 208) was confused by the growth stages of *Dermomurex* and gave the name *"paupercula"* to the small specimens and *"obeliscus"* to the larger, more elongated adults. He also included *D. elizabethae* in the same "species," employing the varietal name *lamellosa* Dunker for this form. However, all of his "varieties" were included in the Mediterranean type species of the genus, *D. scalaroides,* with Dall evidently using the latter in place of a subgeneric assignment. It is true that all of the species of *Dermomurex* are similar, but the resemblances are generic rather than specific.

As was noted under *D. engonatus,* fossil specimens of *Dermomurex* are usually very scarce. *D. pauperculus* has never been reported from the fossil record but there is a single juvenile specimen from TU 954, Puerto Limon, Costa Rica, in the early Pleistocene beds of the Moín Formation.

*See note, p. 132 under *Aspella senex.*

Subgenus GRACILIMUREX Thiele, 1929

Gracilimurex THIELE, 1929, Handbuch syst. Weichtierkunde, v. 1, p. 289.

Type-species: *Murex bicolor* Thiele, by original designation [*Murex bicolor* Thiele, 1929, *non Murex bicolor* Risso, 1826, *nec M. bicolor* Valenciennes, 1832, *nec M. bicolor* Cantraine, 1835, = *Aspella bakeri* Hertlein and Strong, 1951.]

DERMOMUREX (GRACILIMUREX) ELIZABETHAE (McGinty)

Plate 3, figs. 1, 2

Aspella scalarioides var. *lamellosa* Dunker. DALL, 1889, Harvard Mus. Comp. Zool., Bull., v. 18, p. 208 (*not* of Dunker).

Aspella elizabethae T. McGINTY, 1940, Nautilus, v. 53, no. 3, pl. 10, fig. 7 (Jan., 1940); *ibid.* v. 54, no. 2, p. 63 (Oct., 1940).

[?] *Aspella scalarioides lamellosa* Dunker. M. SMITH, 1953, Illus Cat. Recent Species Rock Shells, p. 18, pl. 14, fig. 5 (*not* of Dunker).

Aspella elizabethae McGinty. NOWELL-USTICKE, 1959, Check List Marine Shells St. Croix, p. 63.

[Aspella] (Dermomurex) elizabethae McGinty. E. H. VOKES, 1971, Bulls. Amer. Paleontology, v. 61, no. 268, p. 44.

Diagnosis: "Shell elongated, obliquely subfusiform, chalkish white, with five or six varices on each whorl; several narrow grooves on the spire and low spiral cords between varices, about six on the body whorl. Nucleus smooth, opaque, apex acute, convex, suture deeply impressed, aperture elliptical, lip expanded and indented, operculum yellow and corneus, canal short, narrow and recurved." (McGinty, 1940)

Dimensions of holotype: height 12.5 mm, diameter 5.8 mm.

Holotype: ANSP 176449.

Type locality: Middle Sambo Shoals, near Key West, Florida.

Occurrence: Recent, south and west Florida; Bahamas to Virgin Islands.

Figured specimens: Fig. 1, ANSP 176449 (holotype). Fig. 2, MCZ 244935; height 14.6 mm, diameter 6.8 mm; Sand Key, 7 miles SW of Key West, Florida.

Discussion: The specimen in the USNM collection originally referred by Dall (1889, p. 208) to "*Aspella scalarioides* var. *lamellosa*" (USNM 545338) represents the species named much later as *Aspella elizabethae* McGinty. The failure to recognize this form as distinct is partly responsible for Dall's misunderstanding of the western Atlantic aspelloids, and he noted that in the species he cited as "*Aspella scalarioides*" (really *D. pauperculus* Adams) "a tendency is often exhibited in two of the normal six varices to grow bigger than the others, besides which the intermediate part of the whorl actually becomes somewhat flattened. A specimen of this sort, especially if the flattening is pronounced, as it sometimes is, looks much like a large white *Aspella hastula* [*i.e., A. senex*], and one such was described by Dunker as *Ranella lamellosa.*" (*ibid.*, p. 209). As is noted in the Introduction, *A. lamellosa* (Dunker) is a synonym of *A. producta,* and does resemble *A. senex,* but the species subsequently named *A. elizabethae,* although it occasionally becomes flattened as to mimic an *Aspella* s.s., nevertheless seems to be more nearly allied with the members of *Dermomurex*.

DERMOMUREX (GRACILIMUREX) cf. ELIZABETHAE (McGinty)

Plate 3, figs. 3, 4

Figured specimens: Fig. 3, USNM 647443; height 18.5 mm, diameter 8.0 mm; TU 759. Fig. 4, USNM 739572; height 16.4 mm, diameter 7.8 mm; Pompano Beach, Florida (dredged fill).

Discussion: Along the Caloosahatchee River, west of Ortona Lock, there is a small area where a peculiar form of *Dermomurex* occurred. The form is figured here, on pl. 3, fig. 3, and it appears to be intermediate between *D. engonatus* and *D. elizabethae.* In this small area, represented only by two localities (TU 759 and 803) on opposite sides of the Caloosahatchee "Canal" no specimens of typical *D. engonatus* were found, only this aberrant form, some dozen or more being taken at the two localities. At these same localities there were a number of other strange occurrences, especially the hitherto very rare *Murex anniae* Smith, previously known from two examples, which was found by the hundreds. These localities were created when the U. S. Corps of Engineers deepened the previous channel in the river and piled the

spoil on both sides. The two prior specimens of *M. anniae* had come from near here at Ortona Lock and it is presumed that they were just fortuitous examples of the species that had wandered a bit far from its usual "home."

All along the Caloosahatchee "Canal" there is an undulating surface contact between the early Pleistocene beds that carry the "Glades" fauna, and the underlying late Pliocene Caloosahatchee Formation. Although the dredgings were made to a uniform depth along the bottom, at various spots one could find (while the dredging was in progress) spoil that ranged in age from the "Glades" (or younger in places) to the middle Pliocene Tamiami Formation. Thus at Ortona Lock we find there was a mixture of "Glades" and Caloosahatchee, indicating that the entire "Glades" section had been penetrated. But at the localities two miles west, there was no mixture and the entire section was in the "Glades" unit. This locality has been discussed by McGinty (1970, p. 54), who concluded that the fauna was indicative of a rocky situation. Certainly the replacement of *D. engonatus* by this intermediate form was not indicative of time as one typical *D. engonatus* has been taken at TU 978, a locality of "Glades" fauna only, but of a different ecology.

It seems a reasonable speculation that this occurrence of an intermediate form between *D. engonatus* and *D. elizabethae* is the point of transition between the two species and the two subgenera *Dermomurex* s.s. and *Gracilimurex*. In most places we have a distinct time break between strata, and the evolving species appear to be delimited by stratigraphic breaks. In south Florida we have an almost continuous record and intermediate forms should be the rule rather than the exception. This theory is complicated slightly, however, by the discovery of the intermediate form still living (or at least until very recently) off Pompano Beach, Florida. In 1970 offshore material was pumped in to "replenish" the beach at Pompano and in this material were found specimens of the "intermediate form" (see pl. 3, fig. 4.) Therefore, the validity of this form as an intermediary between *D. engonatus* and

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PLATE 3

(All figures magnified X 3)

Figures — Page

1,2. *Dermomurex (Gracilimurex) elizabethae* (McGinty) 141

1. ANSP 176449 (holotype); height 12.5 mm, diameter 5.8 mm.
Locality: Middle Sambo Shoals, Florida. Recent.

2. MCZ 244935; height 14.6 mm, diameter 6.8 mm.
Locality: Sand Key, Florida. Recent.

3,4. *Dermomurex (Gracilimurex)* cf. *elizabethae* (McGinty) 141

3. USNM 647443; height 18.5 mm, diameter 8.0 mm.
Locality: TU 759. Unnamed post-Caloosahatchee formation, Florida; early Pleistocene.

4. USNM 739572; height 16.4 mm, diameter 7.8 mm.
Locality: Pompano Beach, Florida. Recent.

5,6. *Dermomurex (Dermomurex) engonatus* (Dall) 136

5. USNM 647444; height 26.4 mm, diameter 11.0 mm.
Locality: TU 797. Pinecrest beds, early Pliocene.

6. USNM 647445; height 18.2 mm, diameter 8.8 mm.
Locality: TU 768. Caloosahatchee Formation, Florida; late Pliocene.

PLATE 3

D. elizabethae becomes less certain. But for the time we shall accept it as such until other evidence proves otherwise. It is not impossible that the transitional form may continue to exist along side the new form for a short period of time, to ultimately be completely replaced by it. The typical *D. engonatus* is essentially confined to the Pliocene beds in south Florida with but a single post-Caloosahatchee specimen known, that noted above from TU 978.

Subgenus TRIALATELLA Berry, 1964

Trialatella BERRY, 1964, Leaflets in Malac., v. 1, no. 24, p. 149.

Type-species: *Trialatella cunninghamae* Berry, by original designation.

DERMOMUREX (TRIALATELLA) FARLEYENSIS E. H. Vokes, n. sp.

Plate 4, fig. 1

Diagnosis: Protoconch of one and one-half large, bulbous whorls; seven post-nuclear whorls in the adult. Axial ornamentation beginning on the first post-nuclear whorl with six small varices that overlap onto the protoconch. Each succeeding whorl with six thickened and recurved varices, until about the sixth post-nuclear whorl where every other varix disappears, leaving only a buttress at the suture-line to indicate its former presence. Varices with a thin free-standing flange on the dorsal side, best developed on the anterior portion of the varix, along the siphonal canal. Spiral ornamentation faint, consisting of numerous fine threads on early whorls. On about the fourth post-nuclear whorl a slightly larger cord developed at the periphery, giving rise to a faint angulation in the varices where it crosses. Ultimately about six of these vague larger cords on the body-whorl, superimposed on the more numerous, finer spiral threads that cover the surface. A heavy intritacalx completely covering the entire shell; when fresh relatively smooth on the outer surface, but at broken edges small tunnel-like spiral structures visible within; when worn appearing to have fine spiral grooves of approximately the same order of magnitude as the spiral threads on the porcelaneous portion of the shell. Suture appressed, sinuated by the abutting varices, which are aligned in a slightly curving line up the spire. Aperture oval, with a narrow raised rim in advance of the terminal varix. On the inner side of the outer lip about five small denticles, on the anterior half of the lip only, that at the juncture of the siphonal canal the largest, Inner lip smooth, appressed at the posterior end, free-standing at the anterior end. Siphonal canal medium in length, open by a slit, slightly recurved at the distal end, forming a small umbilical chink.

Dimensions of holotype: height 14.5 mm, diameter 7.5 mm.

Holotype: USNM 647448.

Type locality: TU 999, Farley Creek, about 900 feet downstream from bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun County, Florida.

Occurrence: Chipola Formation, late lower Miocene; Florida.

Figured specimen: USNM 647448 (holotype). Other occurrences: TU locality nos. 458, 554,818, 819, 820, 825, 826, 951, 1049.

Discussion: D. (T.) farleyensis in the first species of a line that is clearly differentiated in later stages, culminating in the Recent species that was named as type of a new genus *Trialatella* Berry, 1964. The Recent form has greatly extended varices but this in itself seems insufficient reason for more than subgeneric separation (see pl. 4, fig. 4).

From the other Chipola species of *Dermomurex,* this form may be distinguished by its more alate varices, which have a tendency toward a shoulder angulation. The aperture of *D. farleyensis* is much smaller proportionally than that of *D. matercula* and the siphonal canal is more extended. The spiral ornamentation of *D. matercula* is coarser in nature, with *D. farleyensis* being almost smooth in overall appearance. Essentially the same criteria separate this new species from the French Miocene species *D. tenellus,* which is the same general form as *D. matercula.*

From its descendants, *D. farleyensis* may be separated by its less alate and less angulated varices, and by its shorter siphonal canal. There are four species that seem to be derived from *D. farleyensis.* One is *D. (T.) cunninghamae* (Berry), type of the subgenus, living on the west coast of Mexico, one is *D. (T.) abyssicola* (Crosse), living in the western Atlantic, the third is an Italian Pliocene species *D. (T.) jani,* and the last is *D. (T.) antecessor,* n. sp., discussed next. All four forms are so similar that one can only assume that the Italian species is in the direct line of descent from *D. farleyensis.*

The name of this new species is indicative of its distribution. Although there are a few specimens from the Chipola River, the majority of the individuals have been taken on Farley Creek. The fauna of Farley Creek is distinctive and it is undoubtedly an ecologic factor that controls the appearance of *D. farleyensis*. In numbers of specimens there are 24 from Farley Creek and only nine from the Chipola River, seven of these being from a single locality, TU 554. At this locality other species are found that otherwise commonly occur only on Farley Creek, as was recently noted by H.E. Vokes (1972, table 1) for *Arcopagia fausta*.

DERMOMUREX (TRIALATELLA) ANTECESSOR E. H. Vokes, n. sp.

Plate 4, figs. 5,6

Aspella (Dermomurex) cf. *jani* (Doderlein *in* Bellardi). S.E. HOERLE, 1970, Tulane Stud. Geol. Paleont., v. 8, no. 2, p. 64.

Diagnosis: Protoconch of one and one-half large bulbous whorls, six post-nuclear whorls in the adult. Ornamentation beginning on the first post-nuclear whorl with six small varices that overlap onto the protoconch, continuing with six varices per whorl up to about the fourth post-nuclear whorl when every other one disappears, leaving only a small buttressed node and an indistinct axial rib to mark the former position. Spiral ornamentation extremely faint, consisting of numerous fine lines underlain by about five larger ridges; the one at the shoulder making a faint angulation of the shell, best seen at the varices where a sharp flexture is developed. Where the other ridges cross the varices stronger raised bands are produced on both the ad- and abapertural sides; at the outer edge of the varices a thin free-standing flange extending the entire length of the varix, best developed toward the anterior canal. In life the entire exterior of the shell covered by an extremely thick intritacalx, greatly extending these varical flanges and giving the shell a wider aspect than when the intritacalx is removed. The bands on the varical surfaces also augumented by the intritacalx, especially on the apertural side, where deep pits are formed between the bands. The intritacalx, when unworn, with a massive earthy appearance , but when abraded displaying small spiral tunnels overlain by an axial fibrilar covering, giving a reticulate appearance to the entire surface. Aperture oval, outer lip crenulate; inside the outer lip five small denticles, corresponding to the spaces or pits between the varical bands of the spiral ornamentation. Inner lip smooth, appressed at the posterior end, slightly free-standing at the anterior end. Canal moderately long, open by a slit, somewhat recurved distally, with successive canals divaricating as spurs off the central axis.

Dimensions of holotype: height 17.0 mm, diameter 8.2 mm.

Holotype: USNM 647446.

Type locality: TU 954, hill cut immediately behind Standard Fruit Co. box factory, just west of cemetery at Pueblo Nuevo, about 2 km west of Puerto Limon, Costa Rica.

Occurrence: Unnamed post–Caloosahatchee formation, Florida; Moín Formation, Costa Rica; Pleistocene.

Figured specimen: Fig. 5, USNM 647447 (paratype); height 16.0 mm, diameter 8.1 mm; locality TU 201.Fig. 6, USNM 647446 (holotype). Other occurrences: TU locality no. 953.

Discussion: Although the subgenus *Trialatella* has not been recognized in the western Atlantic prior to this report, there are, in fact, three species from this region referable to the group. Recent representatives of the subgenus occur in waters of 15 to 30 fathoms. The beds at Moín are thought to be deposited in depths of about 30 fathoms, and the Florida occurrence is assumed, on the basis of other fauna, to have been about 25 fathoms in depth, so it is evident that *Trialatella* is an inhabitant of somewhat deeper water than the other species of *Dermomurex,* which for the most part are intertidal. The type-species has been taken only rarely on the west coast of Mexico and there is but a single Recent specimen of *Trialatella* known from the southern Caribbean, off Cape San Blas, Panamá, in 22 fathoms (see below). However, the group is fairly well represented in the Moín Formation, with 20 specimens from two localities, and another single specimen has been taken from the correlative beds of south Florida (TU 201).

This new species may be distinguished from the West Coast *D. (T.) cunninghamae* primarily by its more elongate shape, by its less depressed suture, and by the presence of a strong spiral cord at the shoulder, which gives rise to a marked angulation. The varices are much less expanded in the Pleistocene

specimens than in *D. cunninghamae,* even in examples of the latter that have the intritacalx removed, for this does have the effect of even more greatly extending the varices. *D. antecessor* also has heavier spiral ornamentation than does *D. cunninghamae.*Nevertheless, all of the species of *Trialatella* are very much alike, and differences are minimal. From the Chipola *D. farlayensis,* this new species differs in the relative proportions of aperture and canal length to total shell height. The anterior canal of the Pleistocene form is more attenuated than the older species. From the Recent *D. abyssicola* it differs in having weaker spiral ornamentation and also in its greater elongation.

In the Pliocene of northern Italy there is another species that appears extremely close to *D. antecessor,* but is distinguishable by the stronger spiral ribbing and larger aperture of the Italian species. This is the form originally cited only as "*Murex distinctus* var." by Cristofori and Jan, 1832, subsequently included in a list of nude names as "*M. jani*" by Doderlein, 1862, and only finally described in 1873 by Bellardi, who observed that it could be separated from the similar "*Murex scalarioides*" *(i.e., arlus),* with which it occurs, by the very fine transverse striae, the

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PLATE 4

(All figures magnified X 3)

Figures Page

1. *Dermomurex (Trialatella) farleyensis* E.H. Vokes, n. sp. 144
   USNM 647448 (holotype); height 14.5 mm, diameter 7.5 mm.
   Locality: TU 999. Chipola Formation, Florida; late lower Miocene.

2,3. *Dermomurex (Trialatella) abyssicola* (Crosse) 148

   2. Holotype—after Crosse, 1865, pl. 1, figs. 4,5; height 11 mm, diameter 6 mm.
   Locality: Guadeloupe, Lesser Antilles, 250 fathoms. Recent.
   3. USNM 739571; height 9.0 mm, diameter 4.0 mm.
   Locality: TU R-98, Holandes Cay, off Cape San Blas, Panamá, 22 fathoms. Recent.

4. *Dermomurex (Trialatella) cunninghamae* (Berry) 130
   SUPTC 9502 (holotype); height 18.0 mm, diameter 9.2 mm.
   Locality: Puerto San Carlos, Sonora, Mexico, 15-35 fathoms. Recent.

5,6. *Dermomurex (Trialatella) antecessor* E.H. Vokes, n. sp. 145

   5. USNM 647447 (paratype); height 16.0 mm, diameter 8.1 mm.
   Locality: TU 201. Unnamed post-Caloosahatchee formation, Florida; early Pleistocene.
   6. USNM 647446 (holotype); height 17.0 mm, diameter 8.2 mm.
   Locality: TU 954. Moín Formation, Costa Rica; early Pleistocene.

7. *Dermomurex (Trialatella) arlus* (de Gregorio) 128
   Basel H 16679; height 20.0 mm, diameter 11.5 mm.
   Locality: Castell'Arquato, near Piacenza, Italy. Plaisancian Stage, Pliocene.

8. *Dermomurex (Trialatella) jani* (Bellardi) 146
   Basel H 16680; height 17.3 mm, diameter 8.4 mm.
   Locality: La Zinola, near Savona, Italy. Astian Stage, Pliocene.

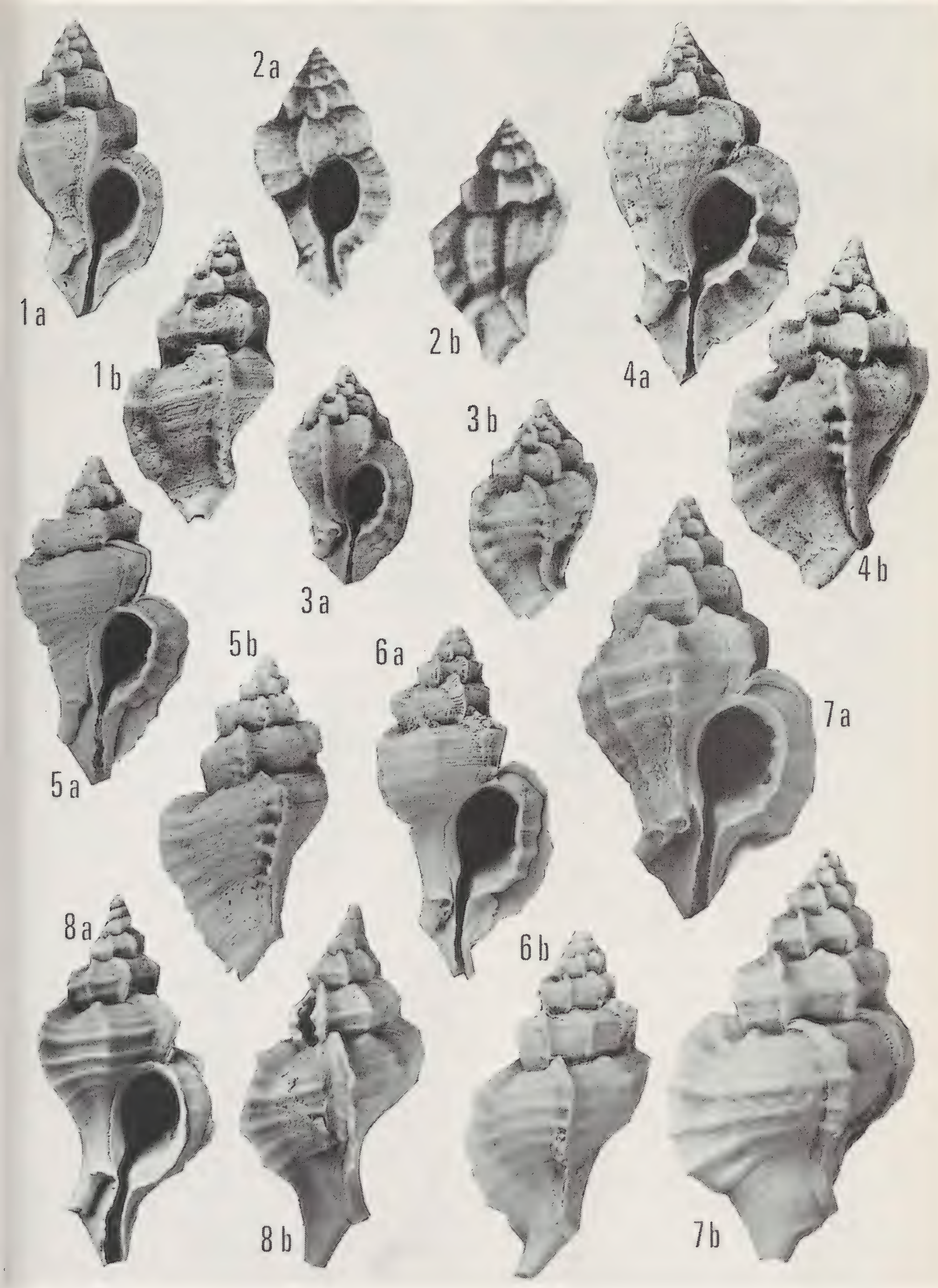

PLATE 4

small and inequal intervarical costae, and by the acute, laminar varices (1873, p. 73). It is also relativėly smaller, as comparison of pl. 4, figs. 7 and 8 will demonstrate.

Considering that *D. jani* is completely unlike any other European species and so like the Chipola and Pleistocene western Atlantic forms, there seems little doubt but that somehow the Italian species is a decendant of the Floridian *D. farleyensis*. There is a parallel situation in the species *Murexiella absona* (Cristofori and Jan, 1832), which again is most closely related to the western Atlantic Pliocene-Recent *Murexiella macgintyi* (Smith), both having their immediate ancestor in the Chipola species *Murexiella shilohensis* (Heilprin). When or how the interchange occurred is not known, but sometime in the early or middle Miocene there was a connection between the Chipola sea and the Aquitaine Basin of southern France. The specimen figured from the Tortonian of Bulgaria by Kojumdgieva and Strachimirov (1960, pl. 40, fig. 7) as *"Aspella (Aspella) scalarioides"* is extremely close to *D. (T.) farleyensis* and may represent the transitional stage. In the Pliocene of the Maritime Alps there is a species of *Dermomurex,* named *"Murex" bisotensis* by Cossmann, 1903, which is probably a synonym of *D. jani.*

DERMOMUREX (TRIALATELLA) ABYSSICOLA (Crosse)

Plate 4, figs. 2,3

Murex abyssicola CROSSE, 1865, Jour. de Conchyl., v. 13, p. 30. pl. 1, figs. 4, 5.

Murex (Pterynotus) abyssicola Crosse. CLENCH and PÉREZ FARFANTE, 1945, Johnsonia, v.1, no. 17, p. 38, pl. 20, figs. 9,10.

[*Aspella*] *(Dermomurex) abyssicola* (Crosse). VOKES, 1971, Bulls. Amer. Paleontology, v. 61. no. 268, p. 12.

Diagnosis: "T. imperforata, trigona, oblonga, tenuiuscala, subtranslucida, peculiariter et tenuissime striato-decussata, coneo-fusca, plerumque plus minusve incrustate; anfr. 6 convexi, embryonales 1½ laeves, albidi, apice obtusiusculo, sequentes trifariam varicosi, varicibus latis, obliquis, foliaceo-nodosis, compressis, subacutis, antice marginatis, inter varices tuberculo prominulo, saepe longitudinaliter diviso ornati, ultimus spiram superans, zona parvula, pallide castanea transversim balteatus; apertura subovata, parva, intus livide fusca; columella subarcuata; margine dextro lato, foliaceo-nodoso, striato-decussato; canali subobliquo, longiusculo, recurvo." (Crosse, 1865)

Dimensions of holotype: height 11 mm, diameter 6 mm.

Holotype: Not found.

Type locality: Guadeloupe, Lesser Antilles.

Occurrence: Recent only, Caribbean Sea.

Figured specimens: Fig. 2, holotype (after Crosse). Fig. 3, USNM 739571; height 9.0 mm, diameter 4.0 mm; locality TU R-98.

Discussion: "Murex" abyssicola was based upon a single juvenile specimen and has not been recognized since its original description. However, the type came from rather deep water (250 fathoms) and this may explain why it has been overlooked for 100 years. Although Clench and Pérez Farfante (1945, p. 39) suggested that the holotype might be in the Caillet Collection at the École de Mines, Paris, correspondance with that institution reveals that the specimen is not there.

The original description leaves little doubt that the species is a *Dermomurex,* mentioning that the surface is ornamented by a "peculiar" and rather elegant system of fine transverse striae. In the Tulane Collections from off Cape San Blas, Panamá, there is one small specimen that seems to be referable to *D. abyssicola.* Certainly it is not a juvenile *D. pauperculus,* which differs in having a small spine-like angulation in each varix, at the shoulder, and also is proportionally more elongate. Comparison of pl. 2, fig. 4, and pl. 4, fig. 3, will show the difference in these two forms, as both specimens have the same number of whorls.

Although obviously very closely related to *D. (T.) cunninghamae,* the small shell from off Panamá is different in having much stronger spiral ornamentation. The presence of the heavy intritacalx masks this difference as it does the different outline of the varix, but specimens of *D. cunninghamae* with the intritacalx removed show an almost completely smooth shell, except on the varical flanges, where faint spiral ridges are

still visible. Likewise the shoulder angulation of *D. cunninghamae* without intritacalx is much more angulate, approximately a right angle turn into the suture, which is deeply impressed, whereas *D. abyssicola* has a gently rounded curve, with or without the intritacalx. There is some doubt as to whether the Panamanian specimen is actually the same as *D. abyssicola.* The great difference in depth is a discrepent factor, and the specimen also lacks the brown band said to circle the base of *D. abyssicola.* However, on the basis of one juvenile specimen, it seems best to treat the two forms as identical. Further collecting may alter this decision.

Dimensions of holotype: height 20.5 mm, diameter 11.0 mm.

Holotype: USNM 647449.

Type locality: USGS 15058, Chickasawhay River, about one mile southwest of Hiwanee, Wayne County, Mississippi (=TU 226).

Paratype A: USNM 498087; height 13.7 mm, diameter 7.8 mm; Chickasawhay River, 1 mile below Shubuta, Wayne County, Mississippi.

Paratype B: USNM 498209; height 11.6 mm, diameter 7.3 mm; Brown's Cave, Leaf River, Smith County, Mississippi.

Occurrence: Red Bluff Clay, lower Oligocene; Mint Springs Marl, middle Oligocene; Mississippi.

Figured specimens: Fig. 2, USNM 498087 (paratype A). Fig. 3, USNM 498209 (paratype B). Fig. 4, USNM 647449 (holotype). Other occurrences: TU locality no. 226.

Subgenus TAKIA Kuroda, 1953

Takia KURODA, 1953, Venus, v. 17, no. 4, p. 190.

Type-species: *Murex inermis* Sowerby, 1841, by original designation *(non Murex inermis* Philippi, 1836, *nec M. inermis* Dujardin, 1837 [?=Philippi])=*Dermomurex (Takia) infrons* Vokes, 1974.

DERMOMUREX (TAKIA) COOKEI

Mac Neil MS, E. H. Vokes, n. sp.

Plate 5, figs. 2–4

Diagnosis: Shell large, with six post-nuclear whorls in adult; protoconch of two large bulbous whorls. Early ornamentation beginning gradually with six small varices that overlap onto the protoconch. Six rib-like varices on each whorl, forming a slightly abaperturally curved spiral line up the spire. Spiral ornamentation minimal, barely perceptible only by fourth or fifth post-nuclear whorl, consisting of faint cords, approximately eight in number on the adult body whorl, but five of these may be stronger. Whorls inflated, suture undulating, varices of each succeeding whorl abutted against the previous one. Aperture rounded; smooth, parietal lip, slightly raised; outer lip with about nine elongate denticles having little correlation with the external ornamentation. Siphonal canal medium in length, open, slightly recurved, becoming more so with increasing size; umbilicus small in juveniles, larger in adult. In life the shell covered by a heavy intritacalx, which seems to have been ornamented by fine spiral grooves, perhaps a dozen or more on the body whorl, but too poorly preserved on type material to be certain.

Discussion: This oldest known *Dermomurex* was described in a manuscript on the fauna of the Vicksburg Group originally prepared by Stearns MacNeil of the U.S. Geological Survey. However, Dr. MacNeil's retirement has forced postponement of publication and so, due to the important position of this species in the history of the *Dermomurex* line in the New World, with Dr. MacNeil's permission it is included here. MacNeil proposed the name *cookei* in honor of C. Wythe Cooke, the noted Tertiary paleontologist, and the writer echoes his sentiment.

This new species from the Oligocene of Mississippi is exceedingly similar to *"Murex" cotteavi** Meunier, from the late Oligocene of France. No material is available of *"M." cotteavi* for comparative purposes, but to judge from the original illustration (Meunier, 1880, pl. 14, figs. 29, 30), and subsequent ones in Cossmann and Lambert (1884, pl. 6, fig. 2, as *"Murex (Trophon) tenellus* Mayer") and Cossmann (1903, pl. 2, fig. 13), the French species is more inflated and also smaller than the American one.

The early species of *Dermomurex* are all very similar and there is not a great deal of difference between the Oligocene *D. cotteavi* and *D. cookei* and the Mio-Pliocene *D.*

*Although named for G.H. Cotteau—(by coincidence also a student of echinoids as is Dr. Cooke), the original spelling of this species name was *"cotteavi,"* and is not to be emended, according to the Code of Zoological Nomenclature, Art. 32.

distinctus. The differences are more a matter of degree than of any striking morphologic change. *D. distinctus* has stronger ornamentation, both axial and spiral, than the earlier forms. In the Old World it is almost certain that *D. cotteavi* give rise to *D. distinctus*. In the New World there is a dual descent, with *D. cookei* presumably giving rise to the later species of *Dermomurex* as well as the species here assigned to *D. (Viator)*. The early Miocene *D.(V.) sexangulus* again is not too different from the Oligocene *D. cookei* and the differences seem to be more in degree of development than in any marked change. The canal in *Viator* becomes more elongate and straight, the spire is shortened, and the ornamentation is strengthened.

D. (T.) cookei is the only western Atlantic representative of the subgenus; but the line still survives in the eastern Pacific *D. (T.) myrakeenae* (Emerson and D'Attilio) (see pl. 5, fig. 7) and in the Indo-Pacific type-species of the subgenus *D. (T.) infrons* Vokes (=*Murex inermis* Sowerby *non* Philippi) (see pl. 5, fig. 1).

Subgenus VIATOR Vokes, 1974

Viator E.H. VOKES, 1974, Malac. Soc. Australia, Jour., v.3, no. 1, p. 4.

Type-species: *Dermomurex (Viator) antonius* Vokes, by original designation.

PLATE 5

(All figures magnified X 3)

Figures — Page

1. *Dermomurex (Takia) infrons* Vokes 130
   Holotype—after Sowerby, 1841, pl. 192, fig. 87; height 25.0 mm, diameter 11.9 mm.
   Locality: Japan. Recent.

2–4. *Dermomurex (Takia) cookei* E. H. Vokes, n. sp. 149
   2. USNM 498087 (paratype A); height 13.7 mm, diameter 7.8 mm.
   Locality: USGS 5263, Chickasawhay River, below Shubuta, Mississippi. Red Bluff Clay, early Oligocene.
   3. USNM 498209 (paratype B); height 11.6 mm, diameter 7.3 mm.
   Locality: USGS 7671, Leaf River, Smith Co., Mississippi. Mint Springs Marl, middle Oligocene.
   4. USNM 647449 (holotype); height 20.5 mm, diameter 11.0 mm.
   Locality: USGS 15058, Chickasawhay River, below Hiwannee, Mississippi (=TU 226). Red Bluff Clay, early Oligocene.

5,6. *Dermomurex (Takia) distinctus* (Cristofori and Jan) 128
   5. Basel H 16681; height 18.0 mm, diameter 10.0 mm.
   Locality: Castell'Arquato, near Piacenza, Italy. Plaisancian Stage, Pliocene.
   6. Basel H 16682; height 13.5 mm, diameter 7.7 mm.
   Locality: Basedasco, near Piacenza, Italy. Plaisancian Stage. Pliocene.

7. *Dermomurex (Takia) myrakeenae* (Emerson and D'Attilio) 130
   Wright Coll. M–309; height 16.3 mm, diameter 9.0 mm.
   Locality: West Mexico. Recent.

8. *Dermomurex (Dermomurex) scalaroides* (Blainville) 127
   USNM 87092; height 18.0 mm, diameter 8.8 mm.
   Locality: Sicily, Italy. Recent.

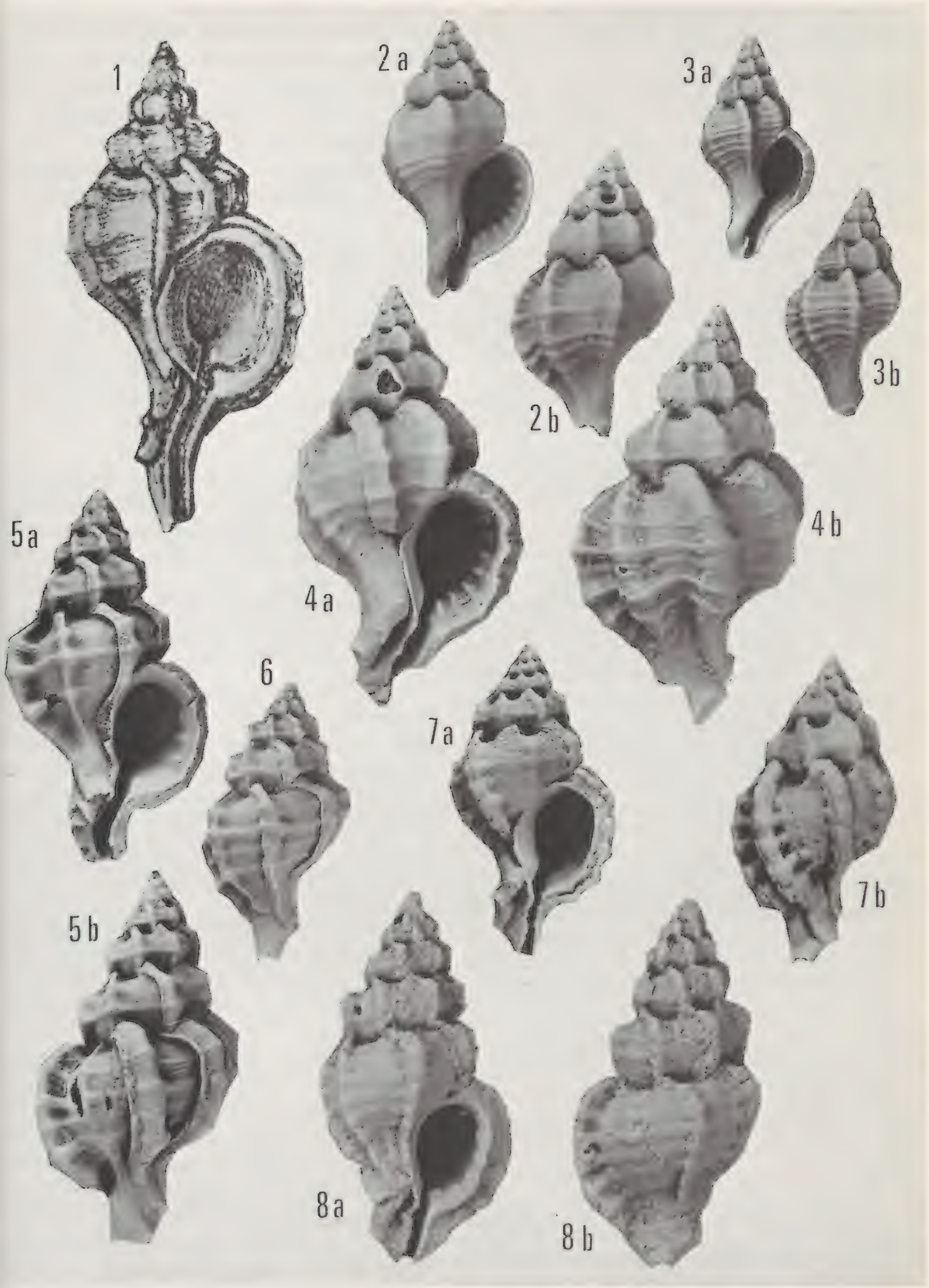

PLATE 5

DERMOMUREX (VIATOR) SEXANGULUS (Dall)

Plate 6, figs. 1,2

Murex sexangula DALL, 1915, U.S. Natl. Mus., Bull. 90, p. 74, pl. 13, fig. 11.
Eupleura sexangula (Dall). MANSFIELD, 1937, Florida Geol. Surv., Bull. 15, p. 132.
"Murex" sexangula Dall. WOODRING, 1959, U.S. Geol. Surv. Prof. Paper 306–B, p. 219.
Murex (Panamurex) gilletteorum E. H. VOKES, 1963, Tulane Stud. Geol., v. 1, no. 4, p. 160, pl. 2, figs. 1a, 1b.
[Poirieria (Panamurex)] gilletteorum (Vokes). E. H. VOKES, 1964, Malacologia, v. 2, no. 1, p. 18.
[Aspella] (Takia) sexangula (Dall). E.H. VOKES, 1971, Bulls. Amer. Paleontology, v. 61, no. 268, p. 97 (with *gilletteorum* in synonymy, p. 54).
Dermomurex (Viator) sexangulus (Dall). E.H. VOKES, 1974, Malac. Soc. Australia, Jour., v.3, no. 1, p. 7, pl 1, fig. 4.

Diagnosis: "Shell small, stout, rather short, with about 6 whorls of which the nuclear one and a half are smooth and rounded, the subsequent whorls subtabulate, with 6 well-developed varices; suture deep, distinct; whorls rather abruptly shouldered but not keeled; varices continuous and somewhat retractive, the line ascending the spire making about a quarter turn; spiral sculpture of about five rounded ridges, one behind the shoulder, subequally spaced, the two near the periphery closest, which are most prominent on the back of the varices and obsolete in the spaces between the varices; besides these there are numerous spiral grooves with wider, flattened interspaces which cover the whole surface and end in minor crenulations on the recurved edges of the varices; axial sculpture only of incremental lines and the varices, which are thick, recurved, longitudinally striate in front, finely crenulate at the recurved edge, with about five projections corresponding to the ends of the spiral ridges, of which the most prominent is at the shoulder; aperture rounded, the outer lip with six or eight feeble lirations internally; inner lip smooth, continous, partly free from the body whorl, canal rather wide, open, with a strong siphonal fasciole; a very narrow umbilical chink present."(Dall,1915)

"Shell large for the group, and heavy. Nucleus unknown, seven post-nuclear whorls in the adult. Axial ornamentation consists of six to seven stout rib-like varices; the spiral ornamentation of four strong, raised ridges, which ride over the varices. Between these conspicuous spiral ridges the shell is patterned with irregular microscopic spiral lirae and axial growth lines giving a semi-reticulate appearance. Aperture ovate, labium heavy, standing free in the anterior portion, somewhat appressed posteriorly. Outer lip denticulate, with about ten more or less well-defined teeth. Canal moderate in length, slightly recurved, and open." (Vokes, 1963)

Dimensions of holotype: height 21.4 mm, diameter 14.0 mm.

Holotype: USNM 165086.

Type locality: Ballast Point, Tampa Bay, Hillsborough County, Florida.

Occurrence: Tampa Limestone, Florida; "Silverdale beds," North Carolina; early lower Miocene.

Figured specimens: Fig. 1, USNM 165086 (holotype). Fig. 2, USNM 644377 (holotype–*Murex gilletteorum* Vokes); height 43.5 mm, diameter 26 mm; locality TU 562. Other occurences: TU locality no. 866.

Discussion: Comparison of the holotype of *D. (V.) sexangulus* with that of *"Murex" gilletteorum* does not immediately show that the two species are synonymous but comparison with smaller unfigured paratypes of *"M." gilletteorum,* approximately the same size as the holotype of *D. sexangulus,* indicates quite clearly that the two are the same. The writer was misled by Mansfield's reference of Dall's species to the genus *Eupleura* and did not consider *D. sexangulus* when describing *"M." gilletteorum.*

The species *"M." gilletteorum* was originally referred to the subgenus *Panamurex* (type: *Murex gatunensis* Brown and Pilsbry) but at the time it was noted the specimens in the type lot do not have the characteristic labial denticulations of *Panamurex.* It was thought perhaps better material might show these. Subsequently Mr. Richard E. Petit, of Myrtle Beach, South Carolina, collected three more well-preserved specimens and they also fail to show these denticulations. Work on the identity of *"Murex" vaughani,* which the writer observed to have an ornamentation similar to *"M." gilletteorum,* although she attributed the similarity to convergence (1963b, p. 152), led to the belated identification of *"M." gilletteorum* as an aspelloid, with the recognition of small remnant patches of intritacalx further corroborating this assignment. There is, nevertheless, still a marked resemblance to the members of *Panamurex,* especially *Poirieria (Panamurex) clarksvillensis* and *P. (P.) laccapoia,* as originally stated, but it is now thought that the resemblance is due to parallelism, for *Poirieria* is almost certainly

ancestral to both *Panamurex* and to *Dermomurex*. The species of *Panamurex* also have an intritacalx, but it is much thinner and less obvious than in the *Dermomurex* species.

Although there are two other species of *Viator* in the New World, in the slightly younger Chipola Formation, they represent a distinct side branch off the main line and the only other species of *Viator* occur in the Miocene and Recent faunas of Australia. As there are no other species known anywhere else in the world, it seems to be the inescapable conclusion that somehow the line made its way from the eastern United States to southern and then northwestern Australia without leaving a trace. The Australian middle Miocene (Balcombian) *D. (V.) asteriscus* (Tate) clearly shows the transition from the relative short-canaled *D. sexangulus* to the very long-canaled Recent *D. antonius* Vokes (compare plate 6, figs. 2, 3, and 5).

DERMOMUREX (VIATOR) VAUGHANI (Maury)

Plate 7, figs. 1,4

Murex vaughani MAURY, 1910, Bulls. Amer. Paleontology, v. 4, no. 21, p. 143, pl. 23, fig. 6.
Murex (Murex) vaughani Maury. GARDNER, 1947, U.S. Geol. Surv. Prof. Paper 142–H, p. 519.
Murex vaughani Maury. BRANN and KENT, 1960, Bulls. Amer. Paleontology, v. 40, no. 184, p. 573.
Murex (Murex?) vaughani Maury. E.H. VOKES, 1963, Tulane Stud. Geol., v. 1, no. 3, p. 102, pl. 1, figs. 2a. 2b.
Murex (Bolinus) vaughani Maury. E. H. VOKES, 1963, Tulane Stud. Geol., v. 1, no. 4, p. 151, pl. 1, figs. 1a. 1b.
[Murex] (Bolinus) vaughani Maury. E. H. VOKES, 1971, Bulls. Amer. Paleontology, v. 61, no. 268, p. 114.

Diagnosis: "Shell small, pyriform, compact, resembling in shape young specimens of *M. messorious* Sowerby of the Pliocene and recent faunas. Whorls about six, the nuclear nearly smooth, the three later whorls bearing each seven varices. On the body whorl the varices are prominent, rounded, somewhat broader than the interspaces. The varices of the shell form nearly continous, sinuous lines from near the apex to the base of the canal. Spiral sculpture of raised lines of which groups of two or three are much stronger and stand out prominently from among alternating feebler spirals. Outer lip with about ten strong internal lirae; aperture oval; canal not quite half the length of the shell." (Maury, 1910)

Dimensions of holotype: height 22.5 mm, diameter 14.0 mm.

Holotype: PRI 3461.

Type locality: "Baileys Ferry, Florida." TU 554, east bank of Chipola River, at power line crossing (SW¼ Sec. 17, T1N, R9W), Calhoun County, Florida (here designated).

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimens: Fig. 1, USNM 647450; height 35.5 mm, diameter 23.3 mm; locality TU 825. Fig. 4, USNM 647451; height 15.6 mm, diameter 9.5 mm; locality TU 830. Other occurrences: TU locality nos. 458, 459, 546, 547, 548, 554, 818, 821, 823, 950, 951, 999, 1049, 1050.

Discussion: Although formerly placed in *Murex (Bolinus)* on the basis of generalized shell morphology, especially like that of *M. (B.) cornutus* Linné, work on the paleontology of *Bolinus* led to the realization that this was a result of convergence. The oldest species of *Bolinus*—those that would be contemporaneous with *D.(V.) vaughani*, such as *M.(B.) partschi* Hörnes—bear very little resemblance to the Chipola species, and it is not until the Pliocene that the similar appearing *M. (B.) torularius* Lamarck is developed. (The middle Miocene species that is often cited as *"M. torularius"* is a much higher spired shell, and is better denominated *M. gapus* de Gregorio, 1885.)

The presence of the large flaring inductura on the pariental wall of *D. vaughani*, so much like that in the Recent species of *Bolinus*, cannot be explained at this time. No other species of *Viator* has such a structure. The identical type of inductura appears independently in the modern species of *Phyllonotus* and *Bolinus* (it does not appear in the earlier species of either group). Thus, it does not indicate especially close relationships. It seems reasonable to conclude that this is a morphologic feature that has arisen independently in response to some functional need. A similar type of inductura may be seen in *Murex chrysostoma* Sowerby, generally accepted as a member of *Murex s.s.*

Dermomurex vaughani is now placed with the aspelloids, on the basis of the previously unrecognized intritacalx, but the placement within the subgenus *Viator* is a compromise.

Although this form may be placed in this group with no difficulty, there are two other species that obviously are closely related to *D. vaughani* but have curved siphonal canals more in the manner of *Takia.* Inasmuch as the low spire and the heavy spiral ornamentation seem more akin to *Viator,* all three of these somewhat atypical species are included here. The alternatives are to create yet another subgenus for these abberrant forms or to "stretch" the subgeneric concept; the writer prefers the latter. Certainly these three species represent a distinct side branch off the main *Viator* lineage. They apparently are an evolutionary "dead-end" as there are no other known species that seem to be related to the group.

Since the original discussion of *D. vaughani* in the earlier parts of this series (Vokes,1963a, p. 102, 1963b, p. 151), a number of other examples have been discovered in the Chipola Formation. However, in spite of the lenghty occurrence list cited above, it is never common and most of the localities are represented by only a single specimen or fragments. The original type locality was cited by Maury as "Baileys Ferry, Florida." As has been discussed before (Vokes, 1968, p. 102) there is no Chipola at that place, therefore a better type locality must be designated. Maury (1910, pp. 143–144) named three muricid species all from this same vague site. The locality TU 554 was previously designated by the writer as the type locality for *Hexaplex veatchi* (Maury), and as both *D. vaughani* (Maury) and *Pteropurpura virginiae* (Maury)—the other species in question—all are at TU 554, this probably was her original locality. It is also possible that collections were made all along the Chipola outcropping at the river's edge, and several TU localities actually may be involved. Certainly the species described by Maury from the same "locality" but in a different paper, as *"Pyrazisinus" harrisi* (see Hoerle, 1972, p. 21) occurs only at TU 459, and almost had to have been collected there.

PLATE 6

Figures Page

1,2. *Dermomurex (Viator) sexangulus* (Dall) 152

1. (X 3) USNM 165086 (holotype); height 21.4 mm, diameter 14.0 mm. Locality: Ballast Point, Tampa Bay, Florida. Tampa Limestone, early lower Miocene.
2. (X 1½) USNM 644377 (holotype-*Murex gilletteorum* Vokes); height 43.5 mm, diameter 26.0 mm. Locality: TU 562. Silverdale beds, North Carolina; early lower Miocene.

3. *Dermomurex (Viator) asteriscus* (Tate) (X 3) 153

USNM 157237 (topotype); height 24.4 mm, diameter 15.0 mm. Locality: Muddy Creek, west of Hamilton, Victoria, Australia. Muddy Creek Formation, middle Miocene (Balcombian).

4,5. *Dermomurex (Viator) antonius* Vokes 153

4. (X 20) WAM. 2834–67 (paratype); height 15.7 mm, diameter 8.8 mm. Locality: Legendre Island, Dampier Arch., Western Australia, 23 fathoms. Recent. (Detail of intritacalx).
5. (5a–X 6; 5b–X 3) WAM. 3646-67 (holotype); height 25.7 mm, diameter 13.5 mm. Locality: Sholl Island, Dampier Arch., Western Australia, Recent. (Fig. 5a–section of shell with intritacalx removed to show underlying ornamentation.)

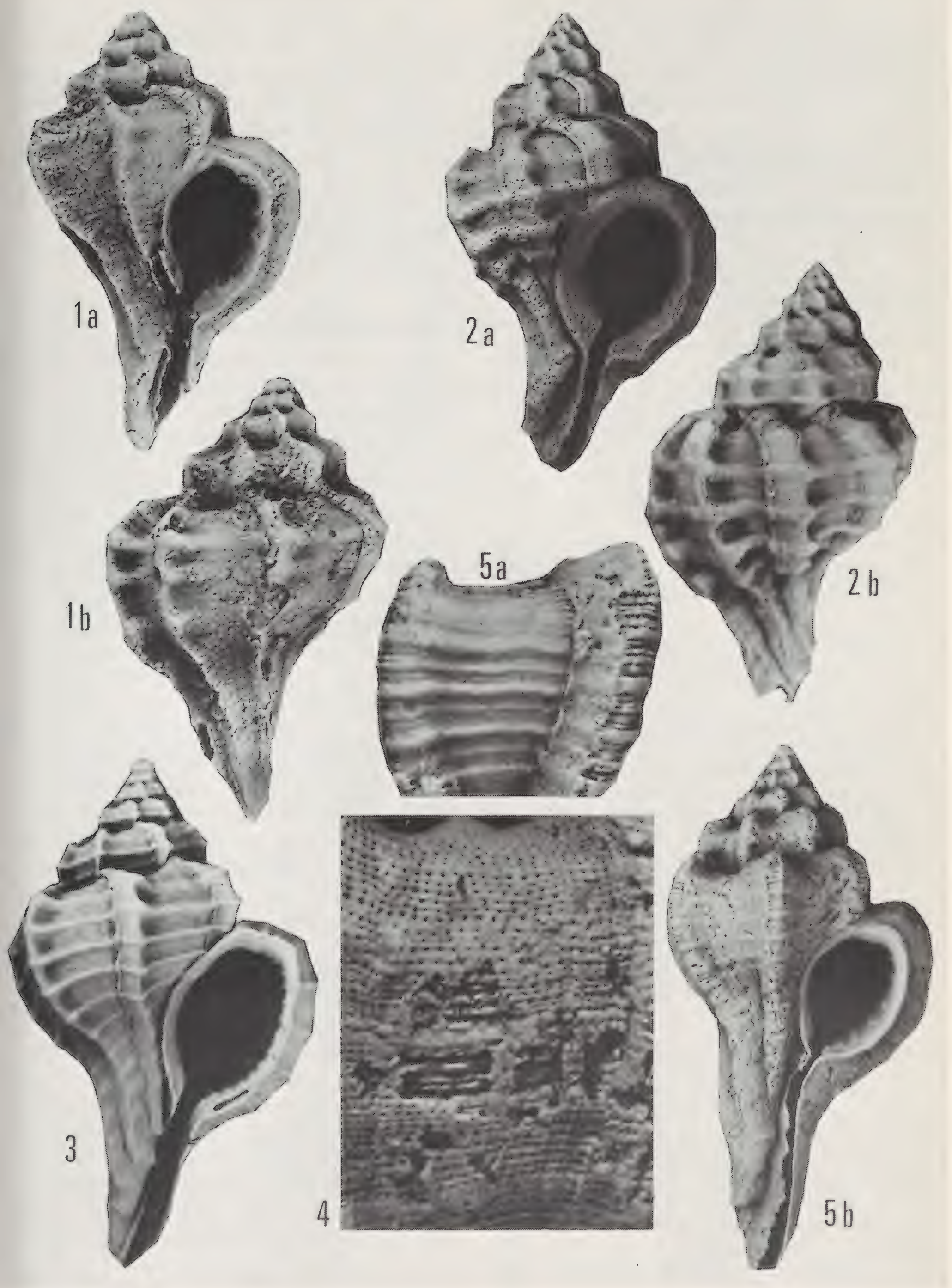

PLATE 6

In 1963 the writer stated (Vokes, 1963b, p. 152) that a fragment, consisting of a siphonal canal, indicated a total height of over 60 mm for this species. However, with much more material now available it seems more probable that this fragment should be assigned to *Murexiella calhounensis* Vokes, and not to *D. vaughani,* for the largest known specimen of the latter is an individual of 45 mm.

DERMOMUREX (? VIATOR) CURVIDUCTUS E. H. Vokes, n. sp.

Plate 7, figs. 2,3

Diagnosis: Shell large for the group; protoconch of two and one-half bulbous whorls; adult with seven post-nuclear whorls. Teleoconch ornamentation begins as faint crescentic varices, visible only at the sutures; becoming broad swollen ridges by third post-nuclear whorl, seven in number on each whorl of teleoconch. Each varix abutting the previous whorl and placed abaxially to its counterpart forming a curved pattern down the spire. Spiral ornamentation of flattened cords, each bearing paired spiral threads upon its surface; six major cords on body whorl and two additional on siphonal canal. Cords obsolete in the intervarical areas, only noticeable where they cross the varices; here forming deep pits between each pair of cords as well as both before and behind the varices, creating the most conspicuous feature of the shell. Shell surface covered with poorly-defined spiral threads between the major spirals, approximately six between each pair. Spire low in proportion, about one-third total shell height. Suture impressed, sinuated by the varical abutments; whorls greatly inflated and sharply constricted into the narrow siphonal canal, which is twisted dorsally at the distal end, the succession of varices producing a long, curved, narrowly open tube. Aperture almost circular; inner side of outer lip with about 12 lirae, apparently not correlated with the external spiral sculpture; inner lip smooth, with a thin, free-standing inductura. In life shell covered with a thick intritacalx but none sufficiently well preserved to determine exact nature.

Dimensions of holotype: height 51.8 mm, diameter 34.5 mm.

Holotype: USNM 647452.

Type locality: TU 830, Ten Mile Creek, at power line crossing about one mile west of Chipola River (SE ¼ Sec. 12, T1N, R10W). Calhoun County, Florida.

Occurrence: Chipola Formation, Florida; late lower Miocene.

Figured specimens: Fig. 2, USNM 647452 (holotype). Fig. 3, USNM 647453 (paratype); height 10.7 mm, diameter 7.5 mm; locality TU 830.

Discussion: Occurring with *D.vaughani,* but so far from a single locality (TU 830), is a new species that is obviously closely related to *D. vaughani* but differs in being larger, smoother, and in having a curved rather than straight siphonal canal. This new species is actually much more like a third species from the Burdigalian beds of Italy and France, *"Murex" taurinensis* Michelotti, 1841. Michelotti's original illustration(1841, pl. 4, figs. 8, 9) shows a gerontic specimen extremely close to the Florida species; however, the illustration given by Bellardi (1873, pl. 6, fig. 10) and the photograph given by Cossmann and Peyrot (1923, pl. 13, figs. 26, 27)*, as well as a young example in the Zurich Collection (here figured, pl. 7, fig. 5), shows that in the younger specimens of *D. taurinensis* the shoulder is more sharply angulated and the body-whorl less inflated. An unfigured paratype of *D. curviductus* that is the same size as the *D. taurinensis* still has the inflated appearance of the larger holotype, so that size is not a factor. The very young examples of *D. curviductus,* such as the paratype here figured (pl. 7, fig. 3), do show a more angulate outline much like the Italian species.

The specimen figured by Cossmann and Peyrot is from Peloua, near Saucats, France, which is the same locality where *Bursa pelouatensis* (Crossmann and Peyrot) occurs. The latter has been reported from the Chipola by the writer (Vokes, 1973, p. 97). The fauna at Peloua is,therefore, of special interest and it seems undeniable that there was some means of communication between the two areas. Many of the species in the two faunas have absolutely no correlation,

*In passing it should be noted that the specimen figured by Glibert (1952, pl. 5, fig. 2) as *"Murex taurinensis"* is not that species but an example of *"Murex" rudis* Borson, a *Hexaplex.*

for there are many Mediterranean elements found at Peloua that never occur in the southern United States, but the two species *D. curviductus* and *D. taurinensis* are too closely alike and too totally distinctive for there not to have been some interchange of faunas. It is inconceivable that the two species represent parallelism.

V. LOCALITY DATA

The following are Tulane University fossil locality numbers:

201. Unnamed post-Caloosahatchee formation, spoil banks at pit just south of Belle Glade, (at Belle Glade Camp), Palm Beach Co., Florida.
202. Caloosahatchee Fm., south bank of Caloosahatchee River, about two miles west of La Belle (SE ¼ Sec. 12, T43S, R28E), Hendry Co., Florida.
203. Caloosahatchee Fm., north bank of Caloosahatchee River, about two miles east of Fort Denaud (SW ¼ Sec. 11, T43S, R28E), Hendry Co., Florida.
226. Red Bluff Clay, Chickasawhay River at Hiwannee, 3½ miles south of Shubuta (Sec. 28, T10N, R7W, St. Stephens Base and Meridian), Wayne Co., Mississippi. (Given in previous papers as the type locality of the Red Bluff Clay, but subsequent work has proved that locality to the about two miles north of 226)
458. Chipola Fm., east bank of Chipola River, above Farley Creek (SW ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
459. Chipola Fm., east bank of Chipola River, steep bank about 1500 feet above mouth of Taylor Lake Branch (NW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
520. Pinecrest Beds, spoil banks, canal 0.9 mile east of Brighton on Florida Highway 70 (Sec. 25, T37S, R32E), Highlands Co., Florida.
529. Caloosahatchee Fm, north bank of Caloosahatchee River, about two miles west of La Belle (SE ¼ Sec. 12, T43S, R28E), Hendry Co., Florida.
536. Caloosahatchee Fm., south bank of Caloosahatchee River about one mile east of La Belle (Sec. 3 & 4, T43S, R29E), Hendry Co., Florida. (Designated as type locality of the Caloosahatchee Formation by Olsson *in* Olsson and Petit, 1964, p. 519.)
539b. Caloosahatchee Fm., Shell Creek (lower beds), about eight miles east of Cleveland (Sec. 30, T40S, R25E), Charlotte Co., Florida.
546. Chipola Fm., Ten Mile Creek, about 1 3/4 miles west of Chipola River (NE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida (=USGS 2212, "one mile west of Bailey's Ferry.")
547. Chipola Fm., west bank of Chipola River, about 2000 feet above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
548. Chipola Fm., west bank of Chipola River, at bend about 1800 feet south of mouth of Farley Creek (NW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
554. Chipola Fm., east bank of Chipola River at power line crossing (SW ¼ Sec. 17, T1N, R9W), Calhoun Co., Florida.
555. Chipola Fm., east bank of Chipola River, about 1000 feet above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
562. "Silverdale Beds," Onslow County marl pit, on south side of Webb Creek, near Silverdale, Onslow Co., North Carolina. (Note: in 1967 this locality was no longer collectable, pit is filled with water.)
579. Caloosahatchee Fm., Miami Canal spoil banks, four miles north of pumping station at Broward county line, Palm Beach Co., Florida.
726. Caloosahatchee Fm., Hendry County rockpit, ½ mile north of Florida Highway 80, three miles west of La Belle (SE ¼ Sec. 14, T43S, R28E), Hendry Co., Florida.
727. Unnamed post-Caloosahatchee formation, borrow pits 2.2 miles east of U.S. Highway 27, 15 miles south of South Bay, Palm Beach Co., Florida.
729. Pinecrest Beds, spoil banks on west side of Kissimmee Canal and east side of Kissimmee River, approximately ½ mile south of U.S. Corps of Engineers Structure 65—D (S ½ Sec. 33, T36S, R33E), Okeechobee Co., Florida.
745. Caloosahatchee Fm., Miami Canal spoil banks, 10.8 miles north of pumping station at Broward county line, Palm Beach Co., Florida.
759. Unnamed post-Caloosahatchee formation, spoil banks north side of Caloosahatchee River, two miles west of Ortona Lock (NE ¼ Sec. 29, T42S, R30E), Glades Co., Florida.
767. Caloosahatchee Fm. and unnamed post-Caloosahatchee formation mixed, spoil banks north side of Caloosahatchee River, five miles west of Ortona Lock (NW ¼ Sec. 36, T42S, R29E), Glades Co., Florida.
768. Caloosahatchee Fm. and unnamed post-Caloosahatchee formation mixed, spoil banks north side of Caloosahatchee River, 5½ miles west of Ortona Lock (NW ¼ Sec. 35, T42S, R29E), Glades Co., Florida.
769. Pinecrest Beds, spoil banks east side of Kissimmee River, 1½ to two miles south of U.S. Corps of Engineers Structure 65—D (NE ¼ Sec. 35, T36S, R33E), Okeechobee Co., Florida.
770. Pinecrest Beds and Caloosahatchee Fm., spoil banks west side of Kissimmee River, 1½ to 3½ miles north of Florida Highway 70 (Secs. 10, 14, 15, and 28, T37S, R33E), Highlands Co., Florida.
797. Pinecrest Beds, material exposed during construction of "Alligator Alley," 13.3 miles

east of Florida Highway 29 (T49S, R32E), Collier Co., Florida.

803. Unnamed post-Caloosahatchee formation, spoil banks south side of Caloosahatchee River, two miles west of Ortona Lock (NE ¼ Sec. 29, T42S, R30E), Glades Co., Florida.

818. Chipola Fm., Farley Creek, 0.1 mile west of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.

819. Chipola Fm., Farley Creek, 0.2 mile west of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.

820. Chipola Fm., Farley Creek (lower beds), at bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.

821. Chipola Fm., Farley Creek, 0.1 mile east of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.

823. Chipola Fm., Farley Creek, south bank about 2000 feet east of bridge of Florida Highway 275 (SE ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.

825. Chipola Fm., Farley Creek, at abandoned mill about ¼ mile west of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.

826. Chipola Fm., Farley Creek, about 0.1 mile west of abandoned mill, which is ¼ mile west of bridge of Florida Highway 275 (on section line between Sec. 20 & 21, T1N, R9W), Calhoun Co., Florida.

827. Chipola Fm., Farley Creek, about ½ mile west of bridge of Florida Highway 275 (SE ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.

830. Chipola Fm., Ten Mile Creek, at power line crossing about one mile west of Chipola River (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.

866. "Silverdale Beds", marl pit on north side of Webb Creek and east side of unnumbered county highway, Silverdale, Onslow Co., North Carolina.

933. Pinecrest Beds, material exposed during construction of "Alligator Alley," 21.5 miles east of Florida Highway 29, Collier Co., Florida.

950. Chipola Fm., west bank of Chipola River, about 200 feet above Farley Creek (SW ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.

951. Chipola Fm., Ten Mile Creek, about 1¼ miles west of Chipola River (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.

953. Moín Fm., type locality, Moín Hill, railroad cut and adjacent ditches on road to Sandoval, 4.5 km west of Puerto Limon, Costa Rica.

954. Moín Fm., hill cut immediately behind Standard Fruit Co., box factory, just west of cemetery at Pueblo Nuevo, about 2 km west of Puerto Limon, Costa Rica.

974. Caloosahatchee Fm. and unnamed post-Caloosahatchee formation mixed, north side Caloosahatchee Canal, 2½ to 3½ miles west of center of former Lake Hicpochee (now drained) (unmapped area, T42S, R32E), Glades Co., Florida.

975. Caloosahatchee Fm., spoil banks north side Caloosahatchee River, 0 to ½ mile west of center of former Lake Hicpochee (now drained) (unmapped area, T42S, R32E), Glades Co., Florida.

978. Unnamed post-Caloosahatchee formation, spoil banks at pit on south side of waterworks,

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PLATE 7

Figures Page

1,4. *Dermomurex (Viator) vaughani* (Maury) 153

1. (X 1½) USNM 647450; height 35.5 mm, diameter 22.7 mm.
Locality: TU 825. Chipola Formation, Florida; late lower Miocene.

4. (X 4) USNM 647451; height 15.6 mm, diameter 9.5 mm.
Locality: TU 830. Chipola Formation, Florida; late lower Miocene.

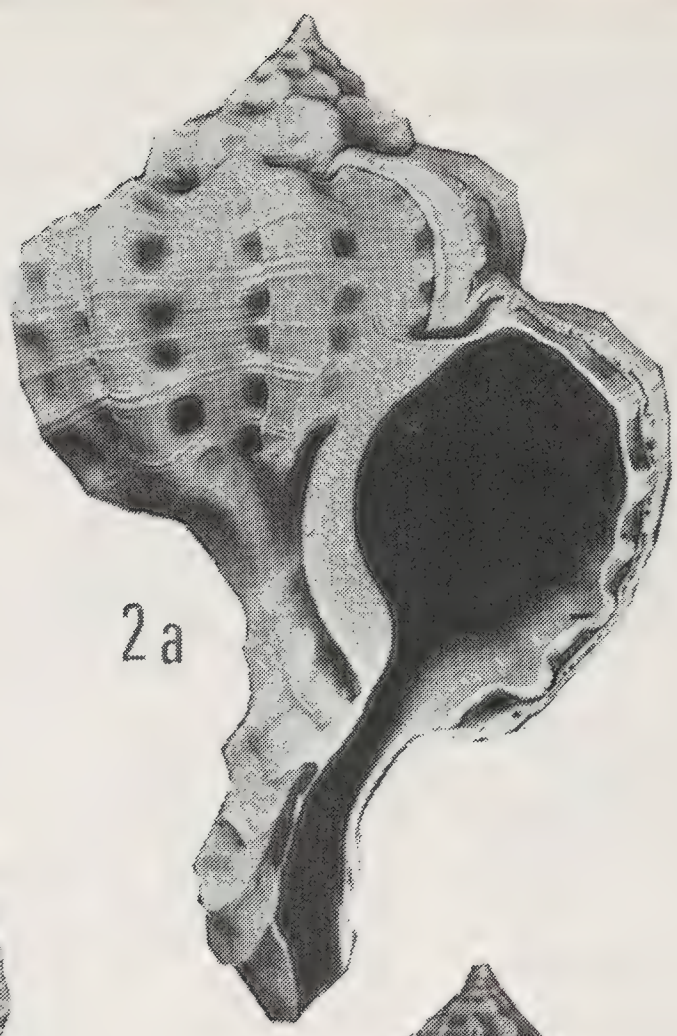
2,3. *Dermomurex (?Viator) curviductus* E.H. Vokes, n. sp. 156

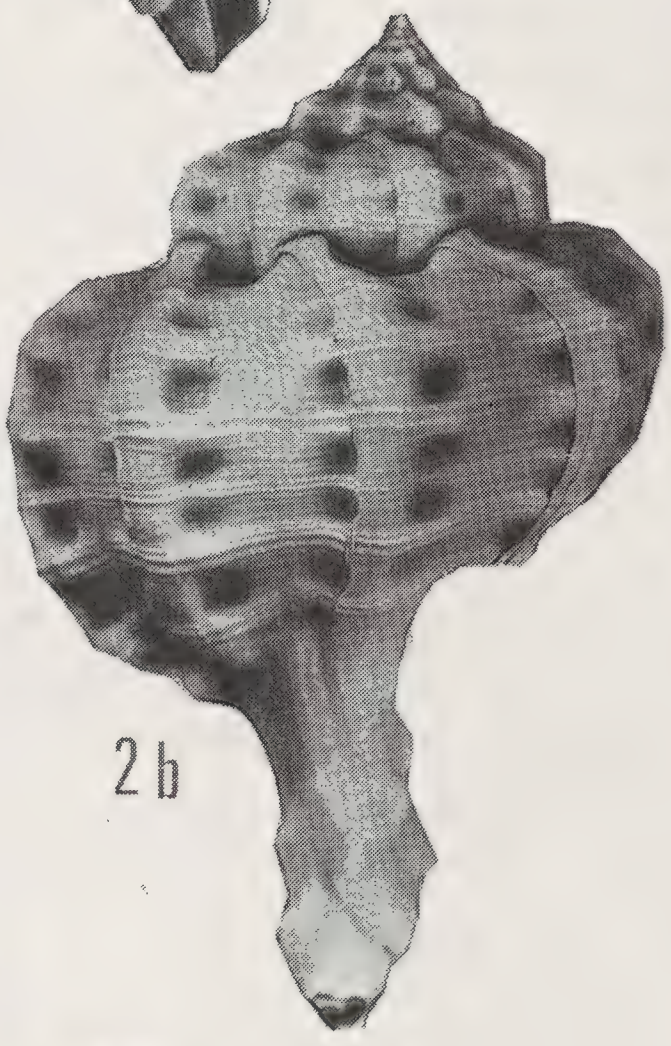
2. (X 1¼) USNM 647452 (holotype); height 51.8 mm, diameter 34.5 mm.
Locality: TU 830. Chipola Formation, Florida; late lower Miocene.

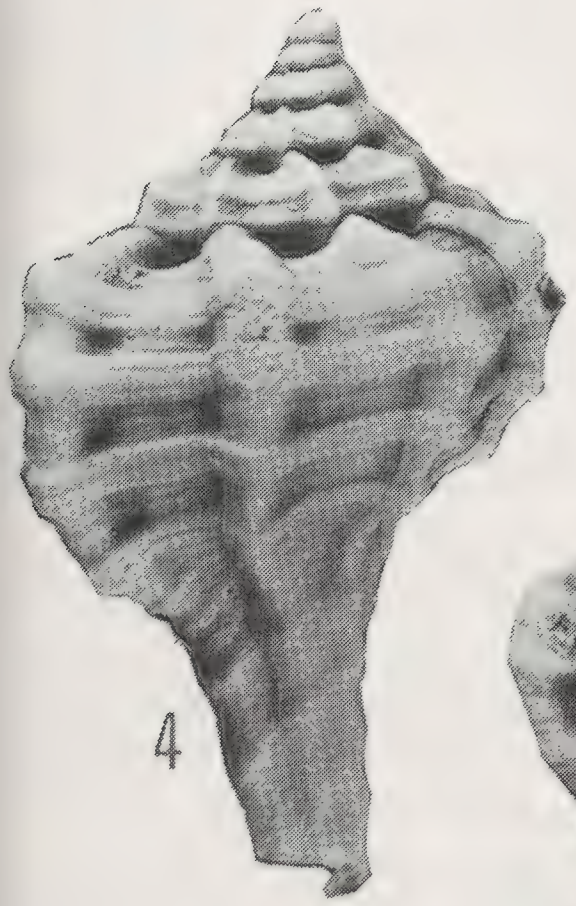
3. (X 5) USNM 647453 (paratype): height 10.7 mm, diameter 7.5 mm.
Locality: TU 830. Chipola Formation, Florida; late lower Miocene.

5. *Dermomurex (? Viator) taurinensis* (Michelotti) (X 2) 156

Basel H 16683 (topotype); height 23.0 mm (incomplete); diameter 21.7 mm.
Locality: Rio della Batteria, Torino, Italy. Burdigalian Stage, lower Miocene.







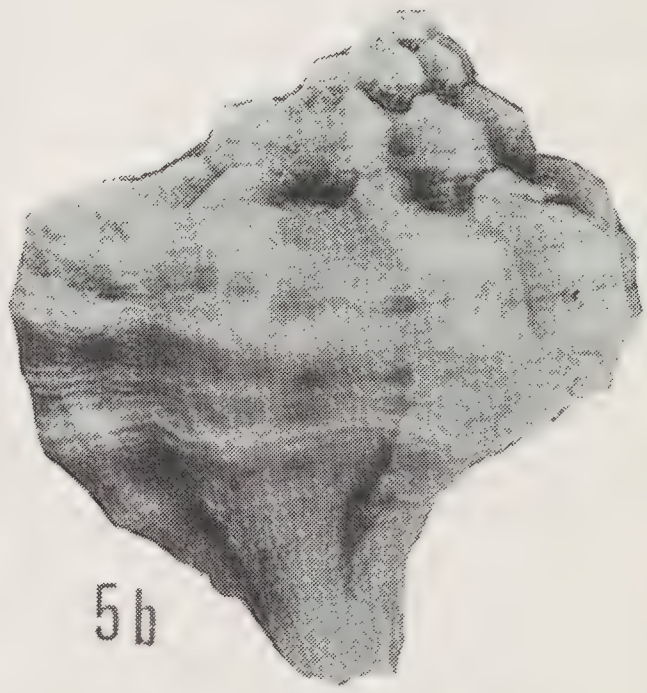


PLATE 7

about 1½ miles northeast of South Bay, Palm Beach Co., Florida.

991. Caloosahatchee Fm., Cochran Rock Pit, 2½ miles west of La Belle, on north side of Florida Highway 80, Hendry Co., Florida.

998. Chipola Fm., Ten Mile Creek, about 1¼ miles west of Chipola River (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.

999. Chipola Fm., Farley Creek, about 900 feet west of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.

1000. Pinecrest Beds, borrow pit at east end of 17th street, (T36S, R19E), about 8 miles east of U.S. Highway 30 at Sarasota, Sarasota Co., Florida.

1023. Caloosahatchee Fm. and unnamed post-Caloosahatchee formation mixed, pits on U.S. Highway 441, at intersection of Florida Highway 717, about one mile east of Pahokee, Palm Beach Co., Florida.

1049. Chipola Fm., Farley Creek, 1.0 mile east of bridge of Florida Highway 275 (NE ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.

1050. Chipola Fm., west bank of Chipola River immediately below power line crossing, and directly across river from loc. 554 (SW ¼ Sec. 17, T1N, R9W), Calhoun Co., Florida.

The following are Tulane University Recent locality numbers:

R-44. Isla Mujeres, open ocean side, Quintana Roo, Mexico.

R-68. Cayos Arcas, reef approximately 100 miles west of Campeche (city), Campeche, Mexico.

R-94. Durate Cays, North Island, north of Porto Bello, Panamá; Lat. 9 degrees 35.8' N, Long. 79 degrees 41' W, shore collection.

R-98. Dredged *Anton Bruun* Cruise 10, NW of Holandes Cay and ENE of Cape San Blas, Panamá; Lat. 9 degrees 37' N, Long. 78 degrees 50.3' W, 22 fathoms.

R-99. Dredged *Anton Bruun* Cruise 10, off northeastern Yucatán Peninsula, Mexico; Lat. 21 degrees 41' N, Long. 86 degrees 34' W, 17 fathoms.

R-166. Barra de Navidad, Jalisco, Mexico; rocky point across inlet from main sand bar.

R-181. Piña, beach on Caribbean coast due west of Gatun, Panamá.

R-263. Gulf of Mexico, about 10 miles off Fort Walton Beach, Florida, 14 fathoms. (Taken by SCUBA diver on coral patches.)

R-269. Akumal, on Caribbean coast about 100 km south of Puerto Juarez, Quintana Roo, Mexico.

R-283. Yukalpeten, sand beach 2.5 km west of Progreso, Yucatán, Mexico.

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WARMKE, G.L., and R.T. ABBOTT, 1961, Caribbean Seashells, Narberth, Pennsylvania. x+348 p., 44 pls., 34 text figs., 19 maps and end pages.

POST SCRIPT

While the above paper was in press, the "unnamed post-Caloosahatchee formation" was finally named. DuBar, in a summary of south Florida Neogene stratigraphy (1974, p. 221), states: "The name Bermont Formation is informally proposed here for the uppermost fossiliferous marine sands exposed along Shell Creek in the Bermont quadrangle, Charlotte County. The formation was referred to as Unit F by DuBar (1962c) who, along with all earlier workers, considered it as a member of the Caloosahatchee Formation. According to Olsson and Petit (1964, p. 521) the unit was first delimited as a separate, post-Caloosahatchee formation by Druid Wilson about 1960. Because Wilson had not named the formation Olsson referred to it as Unit A."

By noting that the name is proposed "informally" DuBar automatically has created a name that really should not be used. The *Code of Stratigraphic Nomenclature* (1972) states that to name a formal rock-stratigraphic unit one must include a "statement of intention to designate a formal unit" (Code, Art. 13). Thus, rather than cutting the Gordian knot, with which we have struggled for so long, he has only added to the complications. However, since the name will undoubtedly pass into the literature in the same way as "Jackson Bluff Formation," "Pinecrest Beds," and the vast majority of the stratigraphic names presently being used in Florida, we might as well become accustomed to it. Even an informal name is better than none.

The type locality of the "Bermont Formation" is the same as TU locality 539 (see above) and is now under the waters of an artificial lake created by a small dam. This may be, in part, what influenced DuBar not to make a formal type locality of it. Although DuBar is of the opinion that the unit is medial Pleistocene in age, the writer and many other paleontologists believe it to be early Pleistocene, correlating with the Moín Formation of Costa Rica, which has been well dated by planktonic foraminifers.

DUBAR, J.R., 1974, Summary of the Neogene Stratigraphy of southern Florida *in* Post-Miocene Stratigraphy central and southern Atlantic Coastal Plain, R.J. OAKS, JR. and J.R. DUBAR, editors, Utah State University Press, p. 206-231, figs. 1-5, tables 1-7.

NOTES ON THE FAUNA OF THE CHIPOLA FORMATION-XVIII

SOME NEW OR OTHERWISE INTERESTING MEMBERS OF THE CALYPTRAEIDAE (MOLLUSCA: GASTROPODA)

EMILY H. VOKES
TULANE UNIVERSITY

I. CALYPTRAEA (TROCHITA)

Although Gardner (1947) lists several species of Calyptraeidae from all three members of the Alum Bluff Group, some very interesting forms were not known to her. Present work has revealed three species of *Trochita* Schumacher, 1817 (type species: *Trochita spiralis* Schumacher = *Turbo trochiformis* Born), a group not found in the western Atlantic today. The Recent members occur primarily on the west coast of South America, with the species *Calyptraea (Trochita) trochiformis* (Born, 1778), and Mexico, with *C. (T.) spirata* (Forbes, 1852). The modern forms are rock-clingers, and Keen (1971, p. 456) notes that *C. spirata* "may be found clinging tenaciously to the most surf-beaten rocks on exposed coasts." Therefore, the presence of two species of *Trochita* in the Chipola Formation and a third in the Oak Grove Sand is of paleoecological value.

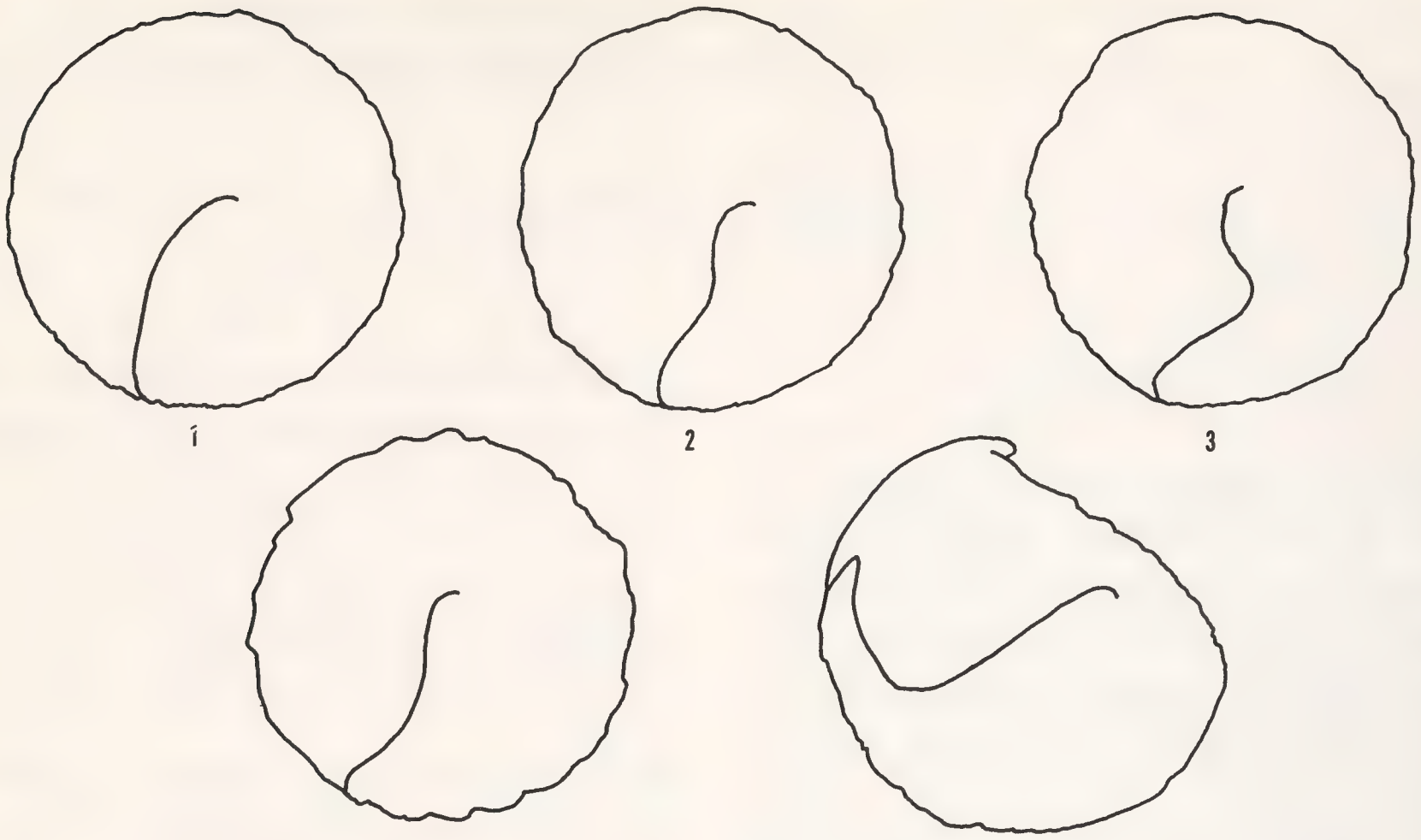
The two Chipola species were not known to Gardner but she did have the Oak Grove form, which she described as *Calyptraea crenata* (1947, p. 562, pl. 56, figs. 1, 2), not recognizing it as a *Trochita.* The holotype is refigured here (pl. 1, fig. 1) and it can be seen that, in spite of its small size (15 mm diameter), it is unquestionably a good *Trochita.* So far as is known the type lot of two specimens are the sole representatives of the species to be taken in the Alum Bluff Group. However, five examples of a closely related, if not identical, form have been collected in the early lower Miocene beds at Silverdale, North Carolina (TU 866). The largest of these is 13 mm in maximum diameter, so it would seem to be a relatively small species.

The two Chipola species are less rare, but nonetheless uncommon. The first is represented by five examples, the largest here figured (pl. 1, fig. 2). The second has a total of 25 specimens from six localities (pl. 1, figs. 3, 5). Not surprisingly the same two species also occur in the Miocene beds of the French Aquitaine Basin. Both forms are cited by Cossmann and Peyrot (1919, pp. 483, 485) as Aquitanian and Burdigalian, thus being exact correlatives of the Chipola forms. The members of *Trochita* are frequently widespread in their distribution; certainly the Eocene *C. (T.) aperta* (Solander, 1766) occurs in both the Old World and the New, and no special significance can be attached to this Miocene occurrence.

The more common of the two Chipola species of *Trochita* is *Calyptraea (Trochita) costaria* Grateloup, 1827. The rarer is *C. (T.) ornata* Basterot, 1825. The latter is marked by ornamentation consisting of small tubules and is probably the direct descendant of *C. aperta,* which also has tubules. The Eocene species is common throughout the London and Paris Basins and also in the Gosport Sand of Alabama. In addition it has been reported from the Vicksburg Oligocene.

From the literature alone it is impossible to know exactly whether a reported species is actually *C. aperta* or *C. ornata.* The chief distinguishing characteristic between the two species is in the nature of the basal septum, and unless this is shown, the specimen could be either. In the younger *C. ornata* the free edge of the septum is straight across; in the Eocene form it is somewhat curved, although not as much as in *C. costaria* (compare text figs. 1–4). Unfortunately these septa are very fragile and are frequently broken, so that of the entire lot of specimens from the Chipola not one *C. costaria* has an unbroken septum. However, the septa of *C. ornata* and *C. costaria* are well figured in Cossmann and Peyrot (1919, pl. 13, fig. 32, and pl. 14, fig. 3).

Calyptraea aperta (as "*C. trochiformis* Lamarck") was reported by Dall (1915, p. 103) from the early lower Miocene Tampa



Text figure 1, *Calyptraea (Trochita) ornata* Basterot. Text figure 2, *Calyptraea (Trochita) aperta* (Solander). Text figure 3, *Calyptraea (Trochita) costaria* Grateloup. Text figure 4, *Calyptraea (Trochita) trochiformis* (Born). Text figure 5, *Crepipatella dilatata* (Lamarck).

Formation. The material is too poor to determine the nature of the septum, but in the correlative Silverdale beds of North Carolina (TU 562) the species that occurs is definitely *C. aperta.* Probably the Tampa form is also.

A similar form has been reported from the middle Miocene of New Jersey and Maryland under the name *Infundibulum perarmatum* Conrad, 1841. There are no specimens in the Tulane collections and from the available illustrations it is impossible to be certain whether the species should be considered a synonym of *C. aperta* or of *C. ornata* but the specimen illustrated by Richards and Harbison (1942, pl. 18, fig. 23) from Millville, New Jersey, looks very much like the Chipola *C. ornata.*

Although the name *C. trochiformis* Lamarck, 1804, has been used extensively for the Eocene species it is a junior synonym of *C. aperta* (Solander). However, it is a source of some confusion in the literature as the Recent West Coast form is now known by the name *Trochita trochiformis* (Born).

The name *Turbo trochiformis* Born, 1778, has been the subject of some nomenclatural controversy, and has been discussed by several authors (especially Palmer, 1963; Robertson, 1963). The original usage of the name is somewhat confused but the reference to a well executed figure in Knorr (1768, *Vergnugender Augen*, pt. 3, pl. 29, figs. 1,2), plus the ruling by the International Commission on Zoological Nomenclature (Opinion 715, 1964) that the name *Trochus conchyliophorus* Born, 1780, refers to the carrier-shell *Xenophora,* thus leaving the name *trochiformis* nomenclatorially available for the *Trochita* from South America, has led to the acceptance by recent authors (*e.g.,* Keen, 1971; Marincovich, 1973) of this name. Frequently in the pre-1964 literature this species is cited as *Trochus radians* Lamarck, 1816, which is a junior synonym.

The name *Patella trochiformis* Gmelin, 1791, is also involved. Several of the references cited by Gmelin apply to one or another species of *Trochita.* Gmelin does not refer to Born and there being no indication that he was using the name in the sense of Born, it is probably just a coincidence. But from his description of the shell as

longitudinally plicate, with the inner lip lateral, it would seem that a *Trochita* was what he was describing. However, his first reference is to a different form figured in Chemnitz (1788, *Conchyl.-Cab.*, v. 10, figs. 1626, 1627), which Rehder (1943, p. 43) as "first reviser" selected as the species to bear the name. This, as Rehder indicated, is now regarded as a member of *Bicatillus (Desmaulus)*, a group more closely related to *Crucibulum.*

In addition to its occurrence on the west coast of South America, the species *C. trochiformis* is also found on the west coast of Africa, from the Cape Verde Islands to Benguela, Angola (Nicklès, 1950, p. 73). If one examines ocean currents one can see this is a plausible distribution. Given a long-lived larval stage, such as *Trochita* has, if a species were to move all the way to the southern tip of South America, the larvae would then get into the eastward-moving Cape Horn Current. From there they would move into the northward Benguela Current, and the next land-fall is southwest Africa. The two occurrences may represent remnants of a formerly continuous range, for the group is found today throughout the Magellanic area, but the species from Tierra del Fuego to Cabo San Antonio, northern Argentina, as well as the Falkland Islands, is slightly different from *C. trochiformis.* It has a more sinuated septum, much like that seen in the figure of *C. costaria* (text fig. 3), which well may be a secondary development in this geographically distinct area.

The western American species of *Trochita* probably all descended from a common ancestor, possibly the form figured by Woodring from the early Miocene La Boca Formation of western Panamá (1973, pl. 72, figs. 12, 16, 19). Closely related to this Panamic species is the Florida Pliocene *C. floridana* (Olsson and Petit, 1964, p. 563, pl. 81, figs. 2, 2a), which is common at some localities in the Brighton facies of the Pinecrest beds. Two other records in the western Atlantic for the latter are the Pliocene Matura Formation of Trinidad (Jung, 1969, pl. 47, figs. 12, 13, as *T. radians*) and the late Miocene beds of the Paraguaná Peninsula of Venezuela (Jung, 1965, pl. 66, figs. 1,2, as *T. cf. radians).* On the basis of over 400 specimens of *C. floridana* in the Tulane collections (373 from a single locality—TU 770) it can be seen that Jung's figured specimens fall well within the rather wide range of variability of this species. The form that occurs in the Gatun Formation of Panamá (Woodring, 1957, pl. 19, figs. 11–14) is the Mexican *C. spirata,* as noted subsequently by Woodring (1973, p. 474).

CALYPTRAEA (TROCHITA) CRENATA Gardner

Plate 1, fig. 1

Calyptraea crenata GARDNER, 1947, U. S. Geol. Surv. Prof. Paper 142-H, p. 562, pl. 56, figs. 1, 2.

Figured specimen: USNM 136053 (holotype); maximum diameter 15.6 mm, height 7.0 mm; locality USGS 2646 (=TU 91).

CALYPTRAEA (TROCHITA) ORNATA Basterot

Plate 1, fig. 2

Calyptraea ornata BASTEROT, 1825, Mém. Soc. Hist. Nat. Paris, v. 2, p. 72, pl. 4, fig. 2.

Figured specimen: USNM 647324; maximum diameter 25.0 mm, height 11.0 mm; locality TU 1051. Other occurrences: TU locality nos. 546,830.

CALYPTRAEA (TROCHITA) COSTARIA Grateloup

Plate 1, figs. 3, 4

Calyptraea costaria GRATELOUP, 1827, Soc. Linn. Bordeaux, Actes, v. 2, p. 82; 1847, Conch. Fossile Bassin Adour, Atlas, pl. 1, figs. 60–63.

Figured specimens: Fig. 3, USNM 647323; maximum diameter 27.0, height 13.0 mm; locality TU 999. Fig. 4, USNM 647322; maximum diameter 24.0 mm, height 10.0 mm; locality TU 459. Other occurrences: TU locality nos. 547, 548,825, 1048.

II. CREPIPATELLA

The second group of Calyptraeidae that is of unusual interest in the Chipola Formation is the otherwise eastern Pacific genus *Crepipatella* Lesson, 1830, a relative of *Crepidula*. So far as is known the Chipola species here described is the first to be recorded outside of that area. However, in Cossmann and Peyrot (1919, pl. 14, fig. 11) there is a specimen figured that is said to be *Crepidula (Janacus) gibbosa* Defrance. This illustrated specimen bears little resemblance to the other two figures supposedly of the same species, and looks suspiciously like the modern *"Crepidula" dilatata* Lamarck, 1822, of Peru and Chile, type species of *Crepipatella*. Unfortunately, only the external view is given of this specimen, whereas the principal differentiating character between *Crepidula* and *Crepipatella* is the nature of the internal septum or deck. In *Crepidula* it is approximately straight across but in *Crepipatella* it is detached along one side (see text fig. 5). One could take a specimen of *Crepipatella* to be a rugose *Crepidula* with the septum apparently broken along one side.

Therefore, there may well be a species of *Crepipatella* in the Helvetian of Aquitaine, but if so it is more closely related to the modern *Crepipatella dilatata* than to the contemporaneous Chipola species. There are several nominal species of *Crepipatella* in western South America, with *"Crepidula" dilatata* the first to be named. Broderip (1835, p. 202) named two additional forms from Peru as *"Crepidula" foliacea* and *"C." strigata,* but large collections made at Antofagasta, Chile (TU R-226), indicate they are probably all the same species. However, Broderip described a third species, *"Crepidula" dorsata* (1834, p. 38) that is very different from *C. dilatata.* It is this latter to which the Chipola species is most nearly related.

There is another possible species of *Crepipatella* in the western Atlantic, *Calyptraea greensboroensis* Martin, based on one specimen from the middle Miocene Calvert Formation of Maryland (1904, pl. 59, fig. 3). The illustration shows a shell with a coiled marginal apex, an ornamentation pattern much like *Crepipatella dilatata,* and unfortunately a broken septum. It may be a specimen of the group named *Bostrycapulus* Olsson and Harbison, 1953 (type: *Patella aculeata* Gmelin, 1791) but the nature of the ornamentation is more like *Crepipatella*, as is the portion of the septum that remains. In addition, the shell has an almost circular outline, again more like *Crepipatella.* Although the Calvert is just slightly younger than the Chipola Formation, there is no possibility that the two occurrences are the same species for the Maryland form has a completely different type of ornamentation.

PLATE 1

Figures Page

1. *Calyptraea (Trochita) crenata* Gardner (X 3) 165
   USNM 136053 (holotype); maximum diameter 15.6 mm, height 7.0 mm.
   Locality: USGC 2646 (= TU 91). Oak Grove Sand, (?) late lower Miocene.

2. *Calyptraea (Trochita) ornata* Basterot (X 2) 165
   USNM 647324; maximum diameter 25.0 mm, height 11.0 mm.
   Locality: TU 1051. Chipola Formation, late lower Miocene.

3, 4. *Calyptraea (Trochita) costaria* Grateloup (X 2) 165
   3. USNM 647323; maximum diameter 27.0 mm, height 13.0 mm.
      Locality: TU 999. Chipola Formation, late lower Miocene.
   4. USNM 647322; maximum diameter 24.0 mm, height 10.0 mm.
      Locality: TU 459. Chipola Formation, late lower Miocene.

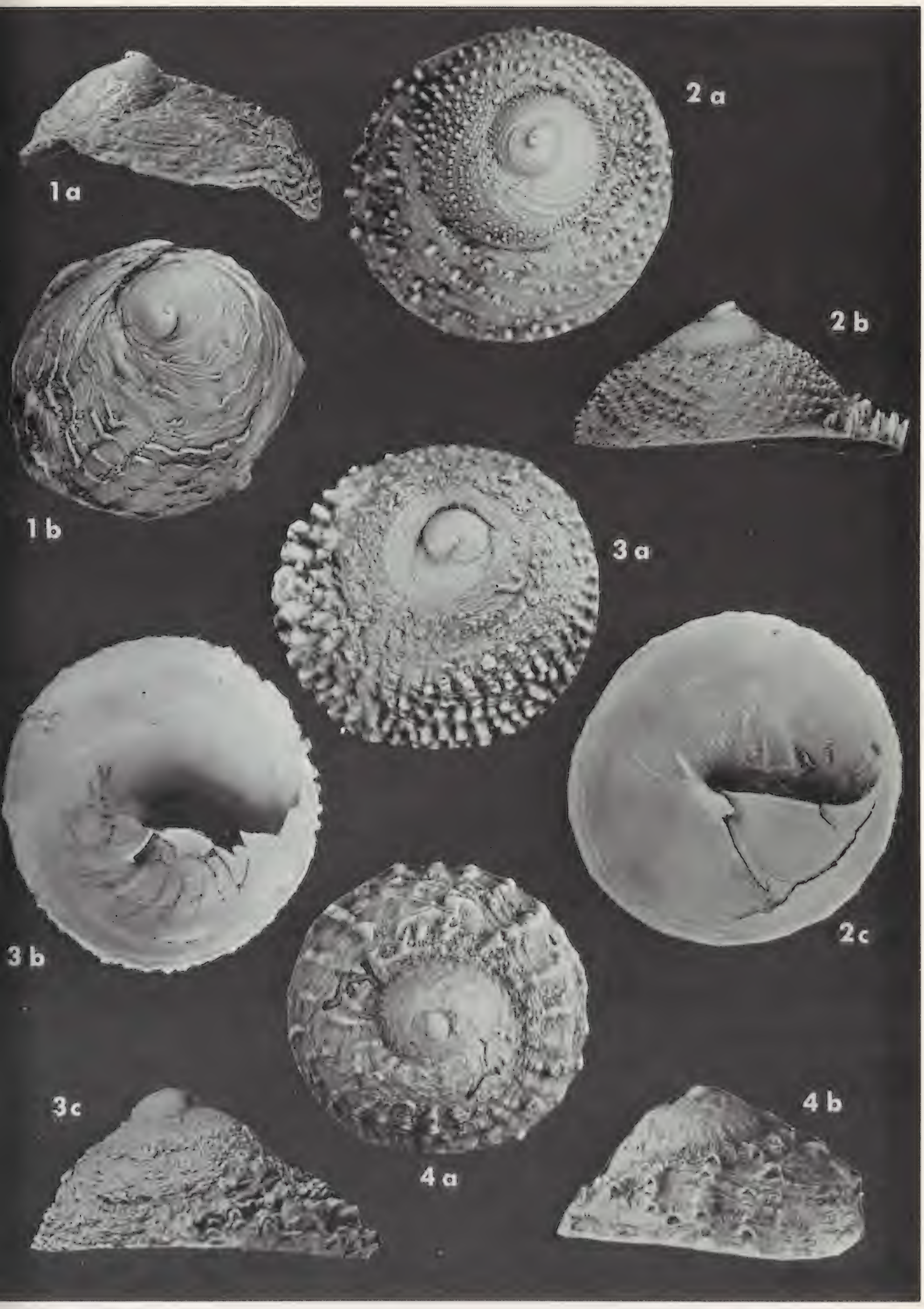


PLATE 1

Jung (1965, p. 500, pl. 66, figs. 7–9) has named a species from the Miocene of the Paraguaná Peninsula, Venezuela, as *"Crepidula ? (Crepipatella ?)" insculpta* that appears to be a form of *Crucibulum* rather than *Crepipatella.* The internal septum is distinctly depressed into an apical hollow and this, combined with the total lack of external sculpture, suggests a species very near *Crucibulum (Dispotaea) constrictum* (Conrad, 1842).

The type lot of *Crepipatella apprimus* n. sp., consists of over 100 specimens, all but four from a single locality in the Chipola–TU 555. The environment of this particular area must have been somewhat unusual, for found here are several species, *e.g., Neritopsis vokesorum* Hoerle, which are confined essentially to this locality, with perhaps a few specimens also being taken at TU 547. The latter we know to have been a coral reef; whole coral heads abound at the site. Geographically TU 555 is about one-quarter mile away but its exact relationship to the reef is uncertain. There is some coral present, but only limited amounts compared with TU 547, and the fauna has many otherwise unknown species. The Trochacea are particularly well represented with numerous specimens of *Calliostoma* spp., *Tegula* cf. *T. fasciata* (Born), *Turbo* cf. *T. haraldi* Robertson, *Turbo* cf. *T. canaliculatus* (Hermann) to mention only a few. Calyptraeidae on the whole are scarce, with the exception of large specimens of *Crucibulum chipolanum* Dall in fair numbers.

CREPIPATELLA APPRIMUS

E. H. Vokes, n. sp.

Plate 2, figs. 1, 2

Description; Shell flattened patelloid, very irregular in outline but generally about the same in maximum and minimum diameter. Protoconch small, of about one and one-half highly polished whorls, in almost the same plane as the remainder of the shell but placed nearer to one edge than to the center. A small smooth raised part encircling the polished portion of the protoconch, like a small cap, ending abruptly at a "drop-off" into the stronger external ornamentation, which consists of strong costae radiating out from the apex. Ornamentation extremely variable, the number of costae ranging from about 12 to 20, increasing with larger size by intercalation. The costae nodulated along their length at irregular intervals in accord with the concentric growth-lines that ring the apex; outer margin crenulated by the raised costae. Internal platform similar to that of *Crepidula* but more cup-like, and detached along one margin.

Dimensions of holotype: maximum diameter 14.4 mm, diameter at right angles to maximum, 12.5 mm, height 3.5 mm.

Holotype: USNM 647331.

Type locality: TU 555, east bank of Chipola River, about 1,000 feet above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun County, Florida.

Occurrence: Chipola Formation, Florida; late lower Miocene.

PLATE 2

Figures Page

1, 2. *Crepipatella apprimus* E. H. Vokes, n. sp. 168
1. (X 4) USNM 647331 (holotype); maximum diameter 14.4 mm, height 3.5 mm.
2. (X7) USNM 647332 (paratype); maximum diameter 7.0 mm, height 2.5 mm.
Locality: TU 555. Chipola Formation, late lower Miocene.

3. *Cheilea equestris* (Linné) (X4) 171
USNM 647325; maximum diameter 12.8 mm, height 4.5 mm.
Locality: TU 547. Chipola Formation, late lower Miocene.

4–6. *Cheilea uncinata* (Reeve) 171
4. (X 5) USNM 647326; maximum diameter 10.5 mm, height 4.3 mm.
Locality: TU 459. Chipola Formation, late lower Miocene.
5. (X 2) USNM 647327; maximum diameter (incomplete) 24.0 mm, height 10.3 mm.
Locality: TU 821. Chipola Formation, late lower Miocene.
6. (X 3) USNM 739424; maximum diameter 18.4 mm, height 10.0 mm.
Locality: TU R-180, Masachapa, western Nicaragua. Recent.

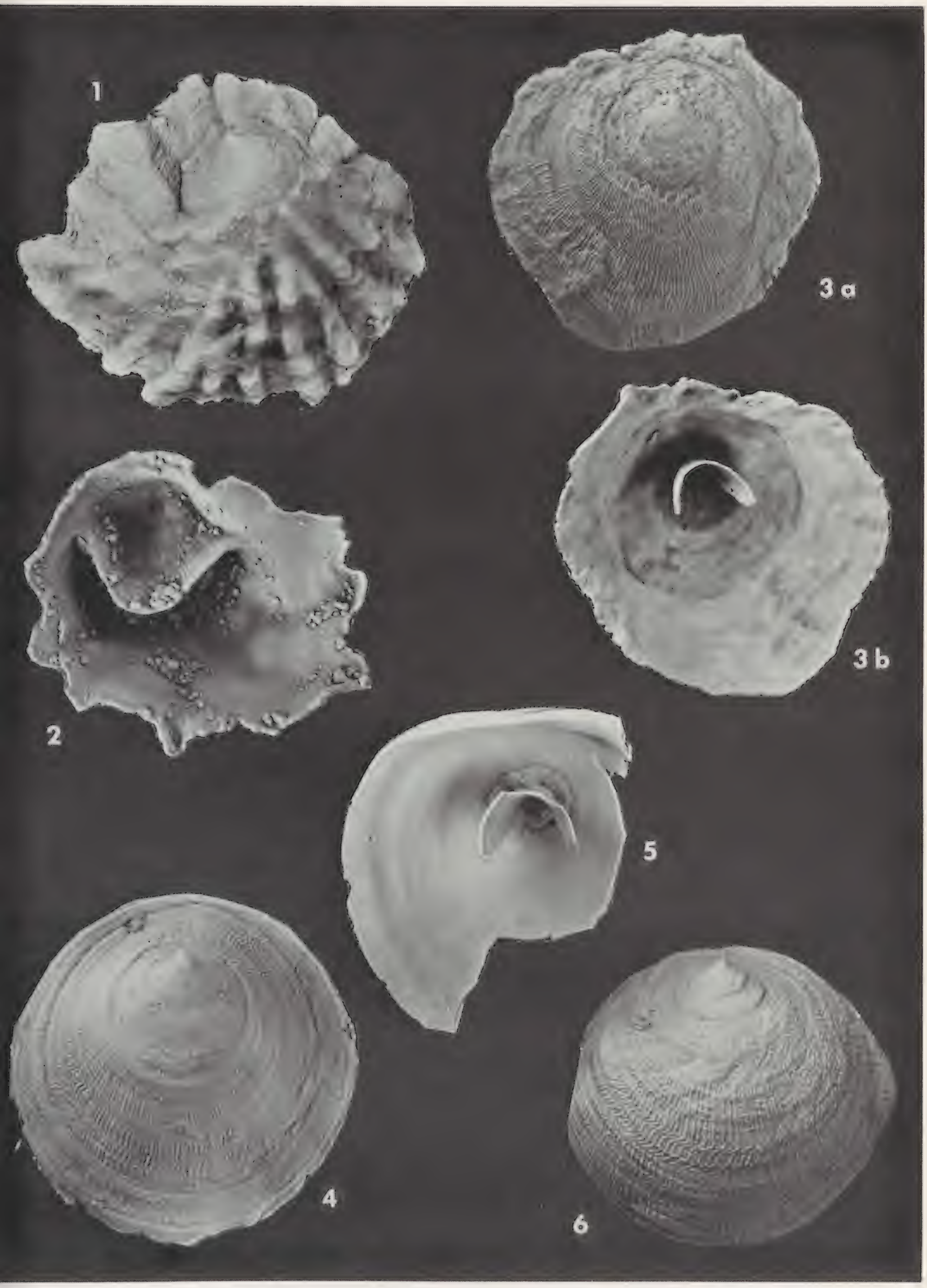


PLATE 2

Figured specimens: Fig. 1, USNM 647331 (holotype). Fig. 2, USNM 647332 (paratype); maximum diameter 7.0 mm, diameter at right angles to maximum, 6.5 mm, height 2.5 mm; locality TU 555. Other occurrences: TU locality nos. 459, 547.

Discussion: This new species is characterized by its small size, the holotype being the largest specimen seen, and by its very irregular ornamentation. *Crepipatella dilatata,* the type of the genus, has more numerous, finer radial costulae and its overall outline is more akin to *Crepidula,* being longer than wide. The nearest form is the Recent West Coast species *C. dorsata* (Broderip), which differs mainly in the shape of the septum. In *C. dorsata* the free edge is nearly stright but in *C. apprimus* it is deeply curved forward.

III. CHEILEA

The third genus-group of Calyptraeidae here reported for the first time in the Chipola Formation is *Cheilea* Modeer, 1793 (type species: *Patella equestris* Linné, s.d., Woodring, 1928, p. 374). Although primarily an Indo-Pacific genus, there are representatives in both the Caribbean and the eastern Pacific. The nomenclature of *Cheilea* has been complicated greatly by authors who seemingly did not recognize the variation within a species. Reeve (1858), who monographed the group (under the generic name *Calyptraea),* included 17 species from the Philippine Islands alone. Other authors have gone to the opposite extreme and placed almost all of the species in synonymy. The truth undoubtedly lies somewhere in between, but the author does not have the comparative material necessary for such a study. The name for the most common Caribbean form is usually cited as *C equestris* (Linné), nominally an Indo-Pacific species. Whether this species has world-wide tropical distribution or whether the Caribbean form is different is not known. In any case, it seems certain that the eastern Pacific *C. cepacea* (Broderip, 1834) is the same as this Caribbean species; therefore should *C. equestris* prove unacceptable for the Caribbean form then *C. cepacea* is available. If geographic separation is considered desirable then *C. stella* (Reeve, 1858), described from Belice (formerly British Honduras), could be recognized.

Cheilea equestris has previously been reported from the Pleistocene of Florida by Hoerle (1970, p. 62) and the Caloosahatchee Formation by Dall (1892, p. 348). Jung also reported it from the Pliocene Matura Formation of Trinidad (1969, p. 469), Woodring figured one of several specimens from the Bowden Formation of Jamaica (1928, p. 375, pl. 30, figs. 1, 2), and it occurs in the Pliocene Agueguexquite Formation of Mexico (TU 638). Perrilliat recently has figured a specimen from the middle Miocene of Santa Rosa, Veracruz, Mexico (1972, p. 59, pl. 26, figs. 1–4). The specimen here figured from the Chipola Formation is thus the oldest record of the species in the western Atlantic, for on the basis of one specimen there is no specific difference to be observed between the lower Miocene and the Recent forms. This is not unexpected, however, as *Cheilea boutillieri* (Cossmann, 1888) from the middle Eocene of the Paris Basin is so nearly the same it should probably also be considered the same species.

In addition to *Cheilea equestris,* there is a second species of this genus in the Chipola, which is the same as the modern Caribbean *C. uncinata* (Reeve, 1858). This species too has an Eocene ancestor, *C. bernayi* (Cossmann, 1885), from the upper Eocene of the Paris Basin. *C. uncinata* may be distinguished from *C. equestris* by its more regularly oval outline, its finer ornamentation, and its larger internal process. Clearly this is a very conservative group with the two lines of descent from the Eocene almost unchanged today. Although Keen (1971) lists no eastern Pacific equivalent of the *C. uncinata-bernayi* line, one specimen from Masachapa, western Nicaragua (TU R-180), in the Tulane Collections is apparently referable to *C. uncinata* (pl. 2, fig. 6).

Gardner had a single specimen of this shell from the Shoal River Formation at Shell Bluff, Shoal River, Florida. She named it as a new species, *Cheilea dryas* (1947, p. 570, pl. 57, figs. 20, 21), but there is no reason to separate it from the Recent *C. uncinata.*

CHEILEA EQUESTRIS (Linné)

Plate 2, fig. 3

Patella equestris LINNÉ, 1758, Syst. Nat., ed. 10, p. 780.

Figured specimen: USNM 647325; maximum diameter 12.8 mm, diameter at right angles to maximum, 12.7 mm, height 4.5 mm; locality TU 547.

CHEILEA UNCINATA (Reeve)

Plate 2, figs. 4–6

Calyptraea uncinata REEVE, 1858, Conchologia Iconica, v. 11, *Calyptraea,* pl. 5, fig. 17.

Cheilea dryas (Dall MS) GARDNER, 1947, U. S. Geol. Surv. Prof. Paper 142-H, p. 570, pl. 57, figs. 20, 21.

Figured specimens: Fig. 4, USNM 647326; maximum diameter 10.5 mm, diameter at right angles to maximum, 10.0 mm, height 4.3 mm; locality TU 459. Fig. 5, USNM 647327; maximum diameter 24.0 mm (incomplete), height 10.3 mm; locality TU 821. Fig. 6, USNM 739424; maximum diameter 18.4 mm, diameter at right angles to maximum, 16.7 mm, height 10.0; locality TU R-180. Other occurrences: TU locality nos. 546, 825, 1050.

ACKNOWLEDGMENTS

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LOCALITY DATA

The following are Tulane University fossil locality numbers:

91. Oak Grove Sand, type locality, west bank of Yellow River, about 100 yards below bridge at Oak Grove (NE ¼ Sec. 20, T5N, R23W), Okaloosa Co., Florida.
459. Chipola Fm., east bank of Chipola River, steep bank about 1500 feet above the mouth of Taylor Lake Branch (NW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
546. Chipola Fm., Ten Mile Creek, about 1 3/4 miles west of Chipola River (NE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida (= USGS 2212, "one mile west of Bailey's Ferry").
547. Chipola Fm., west bank of Chipola River, about 2000 ft. above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
548. Chipola Fm., west bank of Chipola River (NW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
555. Chipola Fm., east bank of Chipola River, about 1000 ft. above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
562. "Silverdale beds," Onslow County marl pit, on south side of Webb Creek, near Silverdale, Onslow Co., North Carolina. (Note: in 1967 this locality was no longer collectable, pit is filled with water.)
770. Pinecrest beds and Caloosahatchee Fm. mixed, spoil banks west side of Kissimmee River, 1½ to 3½ miles north of Florida Highway 70 (Secs. 10, 14, 15, and 28, T37S, R33E), Highlands Co., Florida.
821. Chipola Fm., Farley Creek, 0.1 mile east of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
825. Chipola Fm., Farley Creek, at abandoned mill about ¼ mile west of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
830. Chipola Fm., Ten Mile Creek, at power line crossing about one mile west of Chipola River (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
866. "Silverdale beds." Marl pit on north side of Webb Creek and east side of unnumbered county highway, Silverdale, Onslow Co., North Carolina.
999. Chipola Fm., Farley Creek, about 900 feet west of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
1048. Chipola Fm., Farley Creek, south bank, about 0.8 mile east of bridge on Florida Highway 275 (NE ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
1050. Chipola Fm., west bank of Chipola River immediately below power line crossing, and directly across river from loc. 554 (SW ¼ Sec. 17, T1N, R9W), Calhoun Co., Florida.
1051. Chipola Fm., Ten Mile Creek, south bank, just downstream from large gully on property of Mr. A. Sexton (1967) (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.

The following are Tulane University Recent locality numbers:

R-226. On rocks in front of Hotel Antofagasta, Antofagasta, Chile.
R-180. Beach collection, Masachapa, Nicaragua (Pacific Ocean).

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February 5, 1975

RECENT BOOKS

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PETROGENESIS OF METAMORPHIC ROCKS, by Helmut G. F. Winkler. Published by Springer-Verlag, New York, Heidelberg, Berlin, 1974, Third Edition, xi + 320 pp., illus., $9.80

A NEW SPECIES OF *ENDOPACHYS* (ANTHOZOA: SCLERACTINIA) FROM THE MIOCENE OF FLORIDA

JOHN W. WELLS

DEPARTMENT OF GEOLOGICAL SCIENCES, CORNELL UNIVERSITY

The genus *Endopachys* includes several species of Cenozoic and Recent solitary ahermatypic tropical corals characterized by their free, compressed cuneiform coralla, porous dendrophylliid structures, and septal insertion following the Pourtalès plan. The type species is *E. maclurii* (Lea) from the middle and upper Eocene of the Gulf Coastal Plain (Figs. 4,5). Other species from the same terrain were described by Vaughan (1900) as *E. lonsdalei, E. shaleri,* and *E. minuta.* None are yet known from the later American Cenozoic with the exception of the subject of the present note, and the genus is extinct in America. However, it is still wide-spread in the Indo-Pacific on sandy or mud bottoms in depths of 40 to 350 meters with the species *E. grayi* Milne-Edwards & Haime, 1848, which includes, according to Umbgrove (1950): *E. japonicum* Yabe & Eguchi, *E. oahense* Vaughan, and *E. vaughani* Durham—Recent of the Persian Gulf, Indonesia, Philippines, Japan, Hawaii, Gulf of California; and Neogene of Java, Philippines, Taiwan, Japan. *E. grayi* lacks the distinctive paracostal ridges of the American forms, to which it can only be distantly related.

Order SCLERACTINIA
Suborder DENDROPHYLLIINA
Family DENDROPHYLLIIDAE
Genus ENDOPACHYS Lonsdale, 1845

Type species: E. alatum Lonsdale, 1845, = *Turbinolia maclurii* Lea, 1833. Eocene, Alabama.

ENDOPACHYS TAMPAE Wells, n.sp.
Plate 1, figs. 1–3, 6

Description: Large for the genus, flabelliform, strongly compressed with plane sides and auricular expansions in the longer axis extending below the initial base of the corallum similar to those of *Diploctenium* and some species of *Flabellum.* Calice elongate, bending down steeply at ends, narrow and shallow. From each point of downturning of the calice there extend two thick, rounded paracostal ridges inclined toward and diminishing towards the base. Corallite wall thin, perforate, externally uniformly covered by low, fine, cylindrical or compressed echinulations (Fig. 6). Septa laminar, laterally minutely spinulose. In the holotype there are about 60 larger and 180 smaller septa, the larger numbering about 6 in 10 mm with three shorter ones between each pair of larger. Columella trabecular, narrow.

Dimensions	Holotype	Paratype
Width	53 mm	60 mm +
Height	41 mm	45 mm
Calice width centrally	7 mm	
Calice width laterally	9 mm	
Calice length along curve	95 mm	
Paracostae, max. height	6 mm	8mm

Holotype: USNM 174388 (Figs. 1, 3, 6)
Paratype: USNM 174389 (Fig. 2)

Type locality: Ballast Point, Hillsborough Bay, Hillsborough County, Florida.

Occurrence: Lower Miocene, "Silex Bed" near top of the Tampa Limestone (Cooke, 1945, p. 125) = St. Marks facies of the Tampa Stage (Puri & Vernon, 1959, p. 111).

Remarks: This curious dendrophyllid was recognized many years ago by T. Wayland Vaughan and described by him in an unpublished manuscript on the later Tertiary corals of the United States and the West Indies. In 1915 (p. 18) he furnished W. H. Dall a list of his manuscript names of the species of the Tampa corals, one of which was *"Endopachys tampae,"* a nude name, and later (1919, p. 211) he listed this coral only as *Endopachys.*

The few known specimens are wholly silicified and some calicular details such as the septal plan are obscured. The only complete corallum is the holotype. The paratype is half of a slightly larger individual. There are also several fragments (USNM 174390) of the swollen, nearly solid, resistant lower tips of the alate expansions. The large, strongly compressed corallum with very elongate calice, auricular expansions, and stout paracostae extending downward from the calice margin,

distinguish *E. tampae* from *E. maclurii* (Figs. 4, 5) and related species of the Coastal Plain Eocene.

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February 5, 1975

PLATE 1

Figs. 1, 3, 6. *Endopachys tampae,* n. sp. Holotype, USNM 174388; Figs. 1, 3, lateral and calicular aspects, X 1½. Fig. 6, lateral surface, X 10.

Fig. 2. *Endopachys tampae* n. sp. Paratype, USNM 171389. Left lateral aspect of an imcomplete specimen, X 1½.

Figs. 4, 5 *Endopachys maclurii* (Lea). Calicular and lateral aspects of typical specimens.

Fig. 4. USNM 647320; TU 923, Newton, Newton Co., Mississippi; middle Eocene (Claibornian), X 2.

Fig. 5. USNM 647321; TU 306, Little Stave Creek, Clark Co., Alabama; middle Eocene (Claibornian) , X 2.

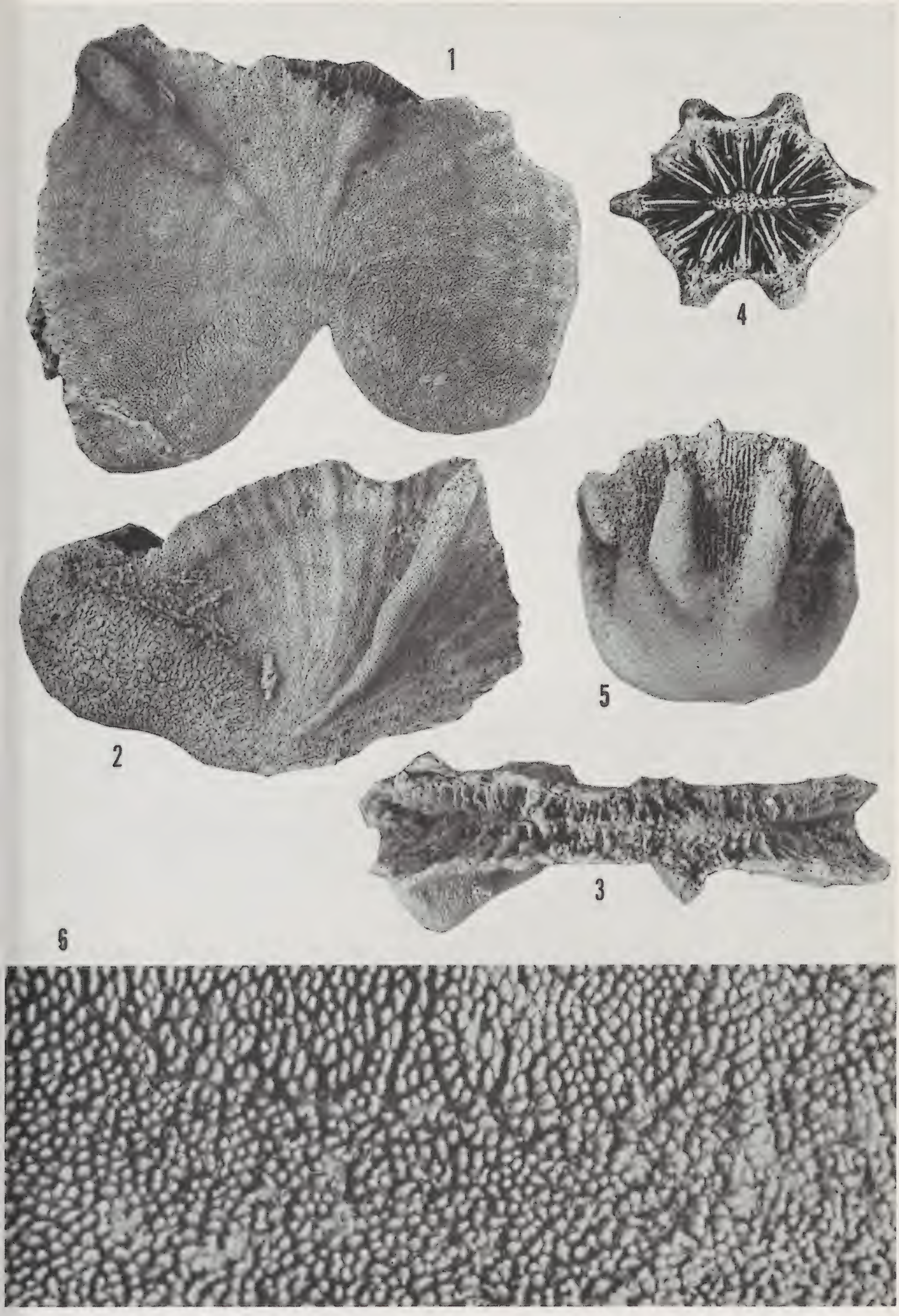

PLATE 1

NERITOPSIS ATLANTICA SARASUA, A PRIOR NAME FOR *NERITOPSIS FINLAYI* HOERLE (MOLLUSCA:GASTROPODA)

ROBERT C. HOERLE

WEST PALM BEACH, FLORIDA

One of the more unfortunate aspects of the current political isolation of Cuba by the United States is the resulting lack of scientific communication. Virtually no Cuban scientific literature is presently received in the United States, and presumably the same is true of U.S. literature in Cuba. Therefore, it is somewhat of a surprise to find that within the space of one year a Cuban and a "Norteamericano" described the first known Recent species of an otherwise Indo-Pacific molluscan genus from the Caribbean region (Sarasua, 1973, Hoerle, 1974).

From the Cuban author's discussion it is obvious that she is totally unaware of the writer's first note on the occurrence of the genus *Neritopsis* in the Miocene of the area (Hoerle, 1972), so that the resulting description of the living example is in no way a reflection of her knowledge that this line should be expected in the Caribbean. The occurrence of the first note originally prompted the recognition of the Cuban specimens in various collections in the United States, collections made before the present political situation developed. But Sarasua's discovery of the occurrence of the genus in the Cuban fauna was totally independent.

The writer regrets the unnecessary creation of a synonym for *Neritopsis atlantica* and hopes that this note will quickly establish the prior name as the correct one for the second living species of the genus *Neritopsis*.

Dr. William Clench, of the Harvard Museum of Comparative Zoology, one of the few institutions in the United States that presently receives Cuban literature, is responsible for discovering this senior synonym and his interest is appreciated.

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February 5, 1975

REVIEW

HUBERT C. SKINNER
TULANE UNIVERSITY

INTRODUCTION TO QUANTITATIVE PALEOECOLOGY, by R. A. Reyment. Published by Elsevier Publishing Company, Amsterdam, London, New York, 1971, xiii + 226 pp., illus., $19.00

This is the first book devoted to quantitative paleoecology. In this pioneer work, much of the material was necessarily drawn from the author's own researches. It includes many laboratory experiments devised to test various hypotheses. One entire chapter deals with the analysis of orientational data, others with the identification of population-dynamics in fossil associations and with spatial paleoecology. Other topics include identifying the effects of salinity, wave action and transport, predator-prey relationships, and the study of predation. The appendices include one which presents the FORTRAN programs for some of the statistical methods presented in this volume.

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MIDDLE EOCENE CALCAREOUS NANNOFOSSILS AT LITTLE STAVE CREEK, ALABAMA

LAUREL M. BYBELL
GEOLOGY DEPARTMENT, THE GEORGE WASHINGTON UNIVERSITY
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NEW NAME FOR A WESTERN ATLANTIC MARGINELLID

BARRY ROTH
CALIFORNIA ACADEMY OF SCIENCES
SAN FRANCISCO, CALIFORNIA p. 308

TULANE UNIVERSITY OF LOUISIANA

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LAUREL M. BYBELL
GEOLOGY DEPARTMENT, THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON, D. C.

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I. ABSTRACT

The middle Eocene Claiborne Group at Little Stave Creek, Alabama, contains a rich and varied assemblage of coccolithophores, with a significant development of provincial forms such as pentaliths, rhabdoliths, and holococcoliths. The pentaliths of the family Braarudosphaeraceae are especially well-developed in the study area. These provincial forms are known from hemipelagic marine deposits in numerous areas, but are notably lacking or sparse in oceanic pelagic sediments. The pentaliths are rare in contemporary nannofloras, but several other Recent coccolithophores have a provincial distribution that is attributed to a benthonic phase in the life cycle of the organism. Eocene pentaliths and the other provincial species may have had similar limitations; nevertheless, they must have possessed a phase which was capable of traversing the open ocean because the same species occur in hemipelagic sediments on all continents. The apparent provincialism of these forms does not diminish their usefulness because the occurrence of a particular species is synchronous throughout the geographic range of that form. These species are useful, therefore, both as stratigraphic indicators in Paleogene sediments and as environmental indicators of the hemipelagic realm.

II. INTRODUCTION

Calcareous nannofossils, including the coccoliths, discoasters, and associated forms, generally are not considered to be provincial. On the contrary, paleontologists generally have been impressed by the similarity of equivalent-age nannofossil assemblages from widely separated areas (*e.g.,* Bramlette and Riedel, 1954; Hay, *et al.,* 1967). The widespread occurrence of individual species, coupled with their great abundance in fine-grained marine sediments, has made nannofossils ideal tools for long-range correlation and high-resolution biostratigraphy. Differences were noted, however, in some nannofossil assemblages of equivalent ages. Sullivan (1964, 1965) observed that pentaliths—nannofossils constructed of five radially arranged calcite crystallites—occur in great abundance in shallow-water marine strata of the Lower Tertiary in California, but may be scarce or lacking in deep-water marine sediments.

Only with the advent of the Deep Sea Drilling Project did samples from early Tertiary oceanic beds in sections far removed from the influence of continents and shelf seas become available in quantity for study. Investigations of this material revealed the almost complete lack of pentalith genera and several other genera including *Daktylethra, Discolithina, Zygrhablithus, Rhabdosphaera, Blackites,* etc., which are so well developed in the many Tertiary marine deposits exposed on the continents.

The present study was undertaken to gain a better understanding of Lower Tertiary coccolithophores, especially the pentaliths. In the process, an attempt was made to evaluate existing knowledge about these forms and to arrive at a reasonable explanation for their peculiar distribution. The middle Eocene Claiborne Group consists of 235 feet of sediments and, according to Berggren's (1971) time scale, ranges in age from about 43 to about 49 million years B.P. This section was chosen for intensive study because of its unusually well-developed calcareous nannofossil assemblage.

Some of the data and illustrations in this paper occur in a previous publication by Bybell and Gartner, 1972. This information has been included in order to present a more comprehensive study of the coccolithophores from the Claiborne Group at Little Stave Creek.

III. METHODS AND TECHNIQUES

A Zeiss light microscope was used extensively, with supplementary information derived from scanning electron photo micrographs. Specimens were examined from various angles with a light microscope using slides mounted with 30,000cs silicone oil. This made it possible to rotate specimens and determine the gross morphology of some of the more complex or unusual species, such as *Micrantholithus altus* Bybell and Gartner and *Pentaster lisbonensis* Bybell and Gartner. Once the gross morphology was determined, these species could then be accurately related to their scanning electron micrograph equivalents. Sample numbers refer to Bandy's (1949) localities at Little Stave Creek, and the samples may be considered to have come from the same statigraphic levels, insofar as it is possible to relocate previously sampled levels in this section.

IV. MODERN COCCOLITHOPHORES

Coccolithophores are unicellular, biflagellate, golden-brown algae, which produce calcareous platelets during some phase of their life cycle. These plates may be holococcoliths, which are constructed of uniform calcite crystals, or the more common heterococcoliths, which are constructed of variously shaped calcareous particles. Coccoliths normally form within the cell of the alga, migrate to the surface, and then are extruded to form an external covering. Recently Parke (1971, 1973) has isolated a form that produces calcareous elements in a mucilaginous covering around the outside of the cell. Some of these forms closely resemble species of the genus *Tetralithus,* while others are somewhat similar to nannoconids. The production of these calcareous plates appears to be light-dependent, but the exact function of the coccoliths is unclear. An organic layer of unknown composition coats each coccolith which retards calcite dissolution of the coccolith. Coccolithophores are herein placed in the kingdom Protista. They are mainly photosynthesizers, but under certain conditions may ingest food particles or absorb nutrients from their surroundings. Most coccolithophores occur in the marine environment, but a few species inhabit brackish or fresh waters. Some modern marine coccolithophores show geographic preferences in their occurrence, inhabiting definite latitudinal belts, and their distribution appears to be closely related to the temperatures of oceanic surface waters. Others prefer a hemipelagic environment *(i. e.,* sharing neritic and pelagic qualities), but most are cosmopolitan. It is in the low and middle latitudes of the open ocean, however, that coccolighophores reach their acme.

Some living species have been studied and seem to have complex life cycles, but the data available result almost exclusively from studying laboratory cultures under conditions which are far different from those in nature. These studies are very useful, however, because they may reveal previously unrecognized relationships between dissimilar stages in the life cycle of a single organism. Some modern coccolithophores have at least two stages in their life cycle and possibly more.

Cricosphaera carterae (Braarud and Fagerland) appears to have several similar phases, which bear coccoliths or organic scales on the surface of the cell. This species also has a benthonic, filamentous stage without scales or coccoliths (Ryans, 1962; Leadbeater, 1970). It has been speculated that most nearshore benthonic members of the Chrysophyta may have a motile stage in their life cycle, although not necessarily one bearing coccoliths (Parke, 1961). A second type of life cycle occurs in *Coccolithus pelagicus* (Wallich), an open ocean form. In this species, a holococcolith-bearing form alternates with a heterococcolith-bearing form (Parke and Adams, 1960; Manton and Leedale, 1969). Schwarz in 1932 described a third type of life cycle in which nonmotile cells are covered with coccoliths and can reproduce sexually. Other equally complex life cycles probably exist. Some may have one phase endophytic in the wall of another alga or symbiotic in an animal (Parke, 1961). Although the phase changes and the conditions which bring them about can be observed in the laboratory, there is some danger in extending these generalizations

to organisms living in the open ocean, because the natural conditions under which these organisms live are impossible to duplicate artificially.

V. ECOLOGY OF FOSSIL COCCOLITHOPHORES

The majority of fossil coccolithophores have worldwide occurrence in marine beds. A few genera have restricted geographical ranges. These genera are found almost exclusively in marine sections which were deposited in the hemipelagic realm of shelf seas and large embayments. Martini (1965, 1970) found the family Braarudosphaeraceae, the genera *Discolithina* and *Scyphosphaera,* and some species of the genus *Rhabdosphaera* characteristic of nearshore deposits. Bukry, *et al.* (1971), considered as characteristically nearshore the genera *Braarudosphaera, Clathrolithus, Daktylethra, Lanternithus, Micrantholithus, Pemma, Peritrachelina, Rhabdosphaera, Transversopontis* and *Zygrhablithus.* The family Braarudosphaeraceae, including the genera *Braarudosphaera, Micrantholithus, Pemma* and *Pentaster,* is especially restricted in its distribution. Eocene representatives of this family occur in hemipelagic deposits in California, Louisiana, Mississippi, Alabama, Mexico, England, France, Germany, Austria, Hungary, USSR, India and the Blake Plateau. They are conspicuously absent from deep-water, open ocean deposits of the same age. A notable exception is the widespread occurrence of one *Braarudosphaera* species in the Oligocene sediments of the South Atlantic recovered during Leg 3 of the Deep Sea Drilling Project (Maxwell, *et al.,* 1970).

Several explanations have been proposed to account for this provincial distribution. According to Bramlette and Martini (1964) and Martini (1965), turbidity and salinity in the nearshore environment may have had significant control over the distribution of phytoplankton living in that area. Martini (1970) stated that paleocurrents may also have been an important factor. Physical-chemical factors may be significant, since the slow sedimentation rate and deep water in the oceanic environment may be unfavorable for the preservation of some species (Gartner and Bukry, 1969; Gartner, 1971). Thus, turbidity, salinity, paleocurrents, or preferential preservation may account for apparent provincialism among certain fossil coccolithophores.

Documented occurrences of living specimens of *Braarudosphaera bigelowi* (Gran and Braaud) include the nearshore area of the Bay of Fundy (Gran and Braarud, 1935) and the open ocean waters of the Sargasso Sea (Gaarder, 1954). Takayama (1972) examined the distribution of this species in nearshore, surface sediments of Sendai Bay off Japan. *B. bigelowi* was recorded only from samples collected in less than 87 meters of water. More comprehensive studies of the Recent occurrences of *B. bigelowi,* the only surviving species of the family Braarudosphaeraceae, and correlation between surface and sediment distribution may shed light on this problem. If living specimens of *B. bigelowi* are cosmopolitan, but are found only in hemipelagic sediments, then their distribution must be controlled by preservation. Clearly, additional observations are needed to verify this distribution. An alternative and more likely possibility is that *B. bigelowi* lives predominantly in the hemipelagic environment and that the distribution of the remains of this organism is indicative of the environment inhabited by it. As noted above, several modern marine phytoplankters prefer hemipelagic conditions. Their restriction to shallow water may be accounted for by an actively photosynthesizing benthonic stage in the life cycle (Parke, 1961; Gaarder, 1971). If a similar benthonic stage, as yet not discovered, exists in the life cycle of *B. bigelowi,* concentration of the species in the hemipelagic realm would be readily explained.

Alternatively, species able to live only in shallow water are unlikely to have worldwide distribution. Smayda (1958) pointed out that large distances can be traversed by phytoplankton only if active cell division is maintained. In deep water the benthonic stage would never develop and the organism would have to remain viable in the pelagic stage for an extended period of time under the assumed unfavorable conditions of the open ocean. In the Eocene, especially in the middle Eocene, the family Braarudo-

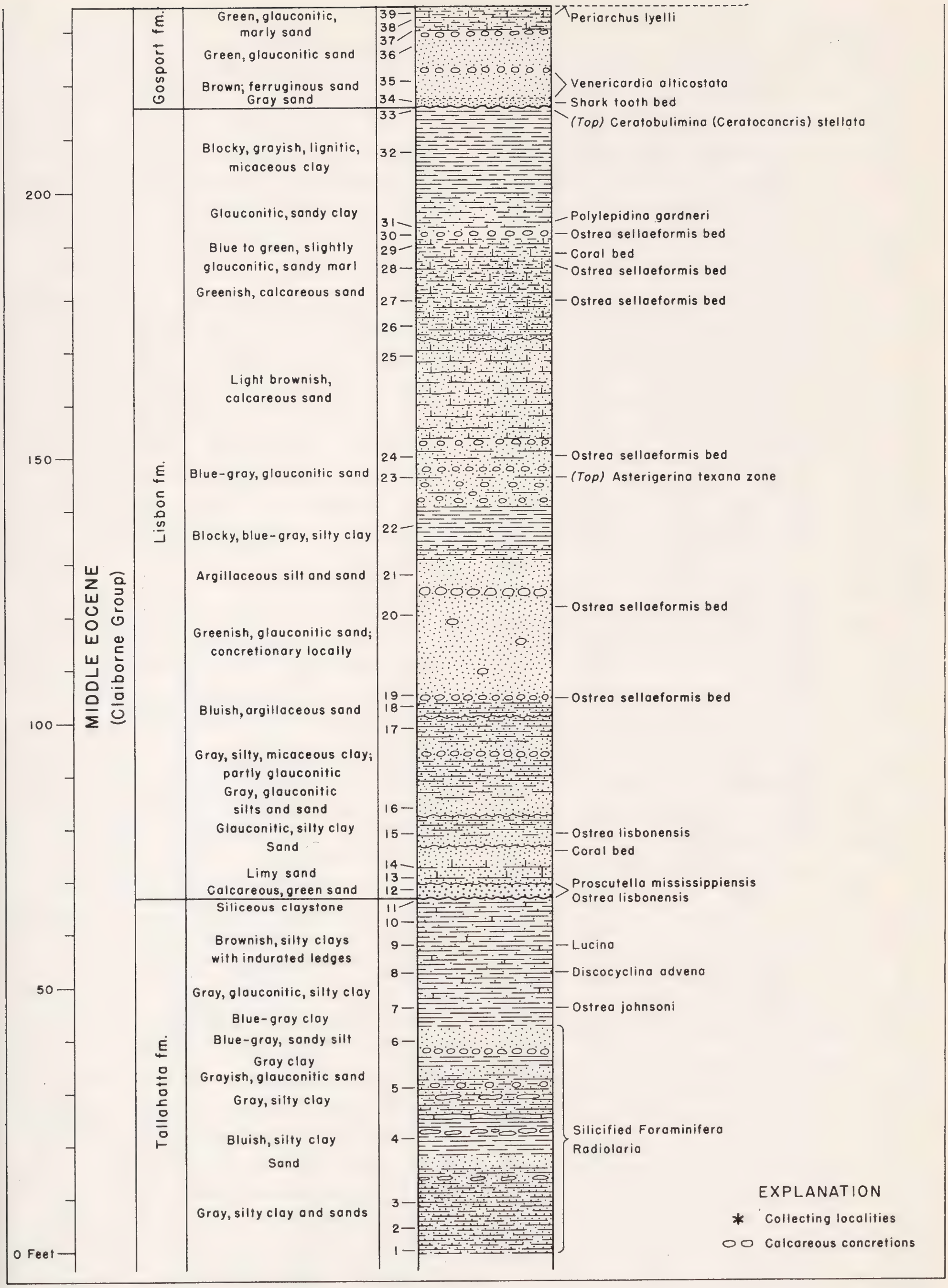

Figure 1. Generalized columnar section at Little Stave Creek, Alabama, indicating sample locations. After Bandy, 1949.

sphaeraceae underwent rapid diversification and speciation. Many of the same species have been recorded from widely separated locations. For example, *Pemma papillatum* Martini has been recorded from Eocene beds in Alabama, Mississippi, Louisiana, Mexico, France and Hungary. Within a relatively short period of time, species somehow were able to spread throughout the shallow waters of the world. One possible mechanism for this distribution would be that the organism, under the influence of a hemipelagic environment, developed coccoliths, but when exposed to different conditions in the open ocean, ceased coccolith production and maintained itself with active reproduction for an indefinite period of time in this non-calcifying phase. Coccolith production would resume when the organism again returned to a hemipelagic environment. Thus, while the remains of the Braarudosphaeraceae are provincial in their distribution, the parent organism clearly would be more cosmopolitan than is indicated by the fossil remains.

The presence of a non-calcifying stage may also explain some of the inconsistencies in the distribution of several open ocean species. *Rhabdosphaera stylifera* Lohmann and *Discosphaera tubifera* (Murray and Blackman), for example, occur in subtropical waters north and south of the equator, but neither occurs in equatorial waters (McIntyre and Bé, 1967). If these species have been geographically separated since the end of the Pleistocene, as data indicate (McIntyre, Bé and Roche, 1970), one would expect some morphological variations to have developed between the populations in the two locations. None exists, however, and it seems probable that there is actual mixing of these two populations, possibly by a eurythermal phase which either has no coccoliths or produces easily destroyed holococcoliths, similar to those found in the *Crystallolithus* stage of *Coccolithus pelagicus* (Wallich).

VI. THE CLAIBORNE GROUP AT LITTLE STAVE CREEK

The middle Eocene Claiborne Group exposed at Little Stave Creek, Alabama, (Figure 1) consists of three formations: the Tallahatta Formation, the Lisbon Formation and the Gosport Formation, which reach a total thickness of 235 feet. The sediments are alternating clays, marls and partially glauconitic sands with scattered oyster beds and concretion layers (S.E.P.M. Guidebook, 1962). Bandy (1949) studied the foraminifers of the Claiborne Group and Gardner (1957) studied the molluscan assemblage.

The presence of shallow water benthonic foraminifers and oysters indicates that these sediments were probably deposited in the neritic zone under fluctuating water conditions. In some strata the microfossils are exceedingly diverse (60 nannofossil species), but other levels may be barren. The exact nature of these fluctuations is unknown, but they may be due to changes in sea level, water circulation, salinity, or water temperature.

Strata with abundant calcareous nannofossils also contain good foraminiferal assemblages, but layers with coccoliths sparse or absent, contain few foraminifers. A few differences were noted, however, between foraminiferal and coccolith distributions. As can be seen on the range chart (Figure 2), coccoliths occur sporadically throughout the Claiborne Group with a marked increase in species diversity at several levels. The upper portion of the Lisbon Formation contains the greatest number of coccolith species. The foraminifers are abundant in the same beds as the coccolithophores, but their greatest species diversity is found in the lower portion of the Lisbon Formation with only a secondary development at the upper levels.

The lower middle Eocene Tallahatta Formation is approximately 65 feet thick at Little Stave Creek and consists of clays, partially glauconitic sands, and a few marls in its upper portion. The lower 40 feet of this formation are noncalcareous and nearly barren of fossils. There are a few silicified species of foraminifera present; the molluscan fauna is poor and normally preserved only as impressions or molds. Calcareous nannofossils are completely absent. Radiolarians are the only common fossils in these

AGE		CALCAREOUS NANNOFOSSIL ZONES. GARTNER, 1971	SAMPLE	SPECIMENS PER TRAVERSE (500X)	SPECIES PER SAMPLE
MIDDLE EOCENE	P 14	HELICOPONTOSPHAERA COMPACTA–CHIASMOLITHUS GRANDIS	39	16	4
			38	180	9
			37	120	6
			36	114	14
			35	172	11
			34	0	0
			33	212	21
			32	440	36
			31	385	31
			30	645	56
			29	381	29
			28	557	40
			27	292	3
			26	361	28
	P 12	PEMMA PAPILLATUM	25	128	1
			24	142	6
			23	37	17
			22	0	0
			21	150	19
	P 11	RETICULOFENESTRA UMBILICA–SPHENOLITHUS FURCATOLITHOIDES	20	99	14
			19	58	16
			18	13	1
			17	0	0
			16	371	21
			15	298	36
			14	323	28
			13	540	23
			12	104	23
			11	110	10
			10	278	19
			9	266	22
			8	87	17
			7	1845	25
			6	42	20
			5	0	0
			4	0	0
			3	0	0
			2	0	0
			1	0	0

FIGURE 2

SPECIES

- BLACKITES CREBER
- BLACKITES SPINOSUS
- BLACKITES TENUIS
- BRAARUDOSPHAERA BIGELOWI
- BRAARUDOSPHAERA CHELOMA
- BRAARUDOSPHAERA DISCULA
- BRAARUDOSPHAERA IRREGULARIS
- BRAARUDOSPHAERA ROSA
- BRAARUDOSPHAERA STYLIFER
- CAMPYLOSPHAERA DELA
- CEPEKIELLA LUMINA
- CHIASMOLITHUS GRANDIS
- CHIASMOLITHUS SOLITUS
- CHIASMOLITHUS TITUS
- COCCOLITHUS CRASSIPONS
- COCCOLITHUS PELAGICUS
- CRUCIPLACOLITHUS STAURION
- CYCLOCOCCOLITHINA FORMOSA
- CYCLOCOCCOLITHINA RETICULATA
- DAKTYLETHRA PUNCTULATA
- DISCOASTER BARBADIENSIS
- DISCOASTER ELEGANS
- DISCOASTER NODIFER
- DISCOASTER SAIPANENSIS
- DISCOLITHINA BICAVEATA
- DISCOLITHINA CRIBRARIA
- DISCOLITHINA MULTIPORA
- DISCOLITHINA VESCA
- DISCOLITHINA WECHESENSIS
- ERICSONIA FENESTRATA
- HELICOPONTOSPHAERA COMPACTA
- HELICOPONTOSPHAERA LOPHOTA
- HELICOPONTOSPHAERA SEMINULUM
- HELICOPONTOSPHAERA RETICULATA
- HELICOPONTOSPHAERA WILCOXONI
- LANTERNITHUS MINUTUS
- LITHOSTROMATION OPEROSUM
- LITHOSTROMATION PERDURUM
- LITHOSTROMATION SIMPLEX
- LOPHODOLITHUS MOCHLOPHORUS
- MARKALIUS INVERSUS
- MICRANTHOLITHUS ALTUS
- MICRANTHOLITHUS ANGULOSUS
- MICRANTHOLITHUS ORNATUS
- MICRANTHOLITHUS PROCERUS
- MICRANTHOLITHUS VESPER
- PEMMA BALIUM
- PEMMA BASQUENSE BASQUENSE
- PEMMA BASQUENSE CRASSUM
- PEMMA PAPILLATUM
- PEMMA ROTUNDUM
- PEMMA SERRATUM
- PEMMA STRADNERI
- PENTASTER LISBONENSIS
- RETICULOFENESTRA BISECTA
- RETICULOFENESTRA UMBILICA
- RHABDOSPHAERA VITREA
- SPHENOLITHUS MORIFORMIS
- SPHENOLITHUS RADIANS
- TRANSVERSOPONTIS EXILIS
- TRANSVERSOPONTIS FIMBRIATUS
- TRANSVERSOPONTIS OBLIQUIPONS
- ZYGOLITHUS DUBIUS
- ZYGRHABLITHUS BIJUGATUS

BARREN INTERVAL

Figure 2. Distribution of calcareous nannofossils in the middle Eocene Claiborne Group at Little Stave Creek, Alabama.

beds. Above this barren zone is the *Ostrea johnsoni* bed, which contains the most diverse molluscan, foraminiferal and calcareous nannofossil assemblages in the Tallahatta. Above the oyster beds are mainly clays with a somewhat less diverse fossil assemblage. The Tallahatta-Lisbon Formation contact is disconformable and there is an abrupt floral and faunal decrease. Just below the contact, there is evidence of burrowing and broken shell fragments are common, probably indicating shallower water.

The Lisbon Formation consists of approximately 150 feet of exposed, predominantly calcareous and glauconitic sands and silty clays with intermittent oyster beds. *Ostrea lisbonensis* reefs occur sporadically in the lower third of the formation and correspond to increased calcareous nannofossil and foraminiferal assemblages. *Ostrea sellaeformis* reefs are scattered throughout the upper portion of the formation and these beds have an impoverished microfossil flora and fauna. This may indicate that *Ostrea lisbonensis* preferred deeper water, more open water conditions, or a different salinity than *Ostrea sellaeformis*. Foraminifers and mollusks are greatest in species diversity in the lower part of the formation, but calcareous nannofossils are at their acme near the top of the Lisbon Formation.

There are approximately 20 feet of glauconitic and ferruginous sands in the Gosport Formation. The megafossils are more numerous than the microfossils. The Lisbon-Gosport Formation contact is unconformable and above the contact is a shell fragment coquina that may indicate a beach deposit. This zone is barren of calcareous nannofossils and foraminifers and the iron present is oxidized. The upper portion of the Gosport is a glauconitic sand with more abundant foraminifers than calcareous nannofossils. No new coccolith species appear in the Gosport and the possibility of reworking cannot be eliminated, although this is not indicated by the foraminiferal evidence.

VII. COCCOLITHOPHORES OF THE CLAIBORNE GROUP

Eighty-one species of coccolithophores, representing 30 genera, were identified in samples from the Little Stave Creek Claiborne Group. There are ten new generic combinations and one new species.

Pentaliths are the most diagnostic forms in the middle Eocene and all four genera are represented in the Claiborne Group. Some pentalith species have considerable morphologic variation, and intermediate forms may exist between species. Other species, for example, *Pemma papillatum* Martini, are distinctive and can be identified even if only represented by fragments. A few pentalith species occur throughout the Lisbon Formation, for example, *Braarudosphaera bigelowi* (Gran and Braarud) and *Micrantholithus vesper* Deflandre, but the majority are restricted to the upper half of the Lisbon and the Gosport formations of late middle Eocene age. Within this zone there is rapid species expansion, six pentalith species occuring in the lower portion of the Lisbon and 18 in the uppermost Lisbon. A similar species diversity is found in middle Eocene deposits of other continents.

Rhabdoliths of the three genera *Blackites, Rhabdosphaera,* and *Cepekiella* are abundant in the Claiborne. Several species, previously illustrated only with light photomicrographs, have now been viewed also with the scanning electron microscope. This has resulted in several generic changes and some species are placed in synonomy. One new species belonging to the genus *Blackites* is described.

Only a few species of *Discoaster* are present in the Claiborne Group and many specimens of these have heavy calcite overgrowths, making identification difficult. Discoasters are more resistant to solution than other calcareous nannofossils probably due to the vertical orientation of the principal optic axis of the crystallites (Bukry, 1971b; Black, 1972). Similarly, these forms are the most likely to have calcite overgrowths (Adelseck, Geehan, and Roth, 1973). Scanning electron photomicrographs

of Claiborne Group coccolithophores show that calcite overgrowth features occur mainly on the discoasters, thus confirming their greater susceptibility to this phenomenon.

There are ten discolith and discolith-related species in the Claiborne Group. Scanning electron photomicrographs reveal at least five basic structural types, which can be used to place species into various genera. Each species must be observed with the electron microscope before it can be properly classified but, once this has been accomplished, it ameliorates the confusion and generic shuffling these forms have been subjected to in previous studies.

The first structural type, as exhibited by *Transversopontis obliquipons* (Deflandre) (Pl. 21, Figs. 1-4), is flat on both the proximal and distal sides. The slightly smaller proximal side has radiating calcite laths, but the distal side has concentrically arranged cycles of elements. Normally there are two central perforations.

Discolithina multipora (Kamptner) (Pl. 20, Figs. 1,4) is representative of the second structural type, which has a concave proximal side with radiating laths and a convex distal side with concentrically arranged elements. The surface bears numerous small perforations. A third structural form is basket-shaped with thin high walls and radiating laths on both sides. Specimens may or may not have a flange and may have up to two central basal perforations. *Transversopontis exilis* (Bramlette and Sullivan) (Pl. 21, Fig. 5) falls within this category.

A fourth type as seen in *Discolithina wechesensis* Bukry and Percival (Pl. 20, Fig. 2) is also basket-shaped, but has thick walls that normally have a series of interior vertical struts. Calcite elements are of the radiating type and specimens may have no central perforation, one perforation, or two.

These four structural types are all represented in the middle Eocene Claiborne Group. Neogene discolith forms possess a fifth type of structure, which is similar to the basal portion of species of the genus *Scyphosphaera*. The concave proximal side has radiating laths while the nearly flat distal side has concentrically arranged crystals. The thick walls rise vertically, ending as a broad, flat upper rim and the base has numerous small perforations.

The species *Trochoaster operosus* (Deflandre), *Marthasterites reginus* Stradner, and *Trochoaster simplex* Klumpp are placed in the genus *Lithostromation* along with *Lithostromation perdurum* Deflandre. Scanning electron photomicrographs reveal that all four species have a similar structure: multiple, circular depressions, each surrounded by a knobby hexagonal ridge and three-fold symmetry (or a multiple, 6, 9 or 12). Their similarity makes it impractical to place them in separate genera with other dissimilar forms.

VIII. ZONATION OF THE CLAIBORNE GROUP

The Claiborne Group at Little Stave Creek is correlated with the middle Eocene section. These sediments, however, previously have not been related to any standard zonation scheme. Martini (1971b) published a calcareous nannofossil zonation, but it cannot be related to Little Stave Creek sediments because the majority of his zonal markers are not found in the Claiborne Group.

Gartner (1971) also published a zonation for the Eocene which can be applied to the coccolithophores of the study area. Gartner recognized five middle Eocene calcareous nannofossil zones:

1. *Discoaster tani* s. l. – *Sphenolithus radians* Zone – Interval from the first occurrence of *Discoaster tani* s. l. to the first occurrence of *Reticulofenestra umbilica* (Levin). This zone is roughly equivalent to Blow's P10 zone.
2. *Reticulofenestra umbilica* – *Sphenolithus furcatolithoides* Zone – Interval from the first occurrence of *Reticulofenestra umbilica* to the first occurrence of *Pemma papillatum* Martini. This zone is approximately equivalent to Blow's P11 zone. The holococcolith *Lanternithus*

minutus Stradner first occurs in this zone.

3. *Pemma papillatum* Zone – Interval from the first occurrence of *Pemma papillatum* to the first occurrence of *Bramletteius serraculoides* Gartner. This zone is roughly equivalent to Blow's P12 zone.
4. *Bramletteius serraculoides* Zone – Interval from the first occurrence of *Bramletteius serraculoides* to the first occurrence of *Helicopontosphaera compacta* (Bramlette and Wilcoxon). This zone is approximately equivalent to Blow's P13 zone.
5. *Helicopontosphaera compacta – Chiasmolithus grandis* Zone – Interval from the first occurrence of *Helicopontosphaera compacta* to the first occurrence of *Hayella situliformis* Gartner. This zone is roughly equivalent to Blow's P14 zone.

Sporadic calcareous nannofossil occurrences at Little Stave Creek make zonation difficult and there may be an error of a few samples on either side of the zonal boundaries. Of Gartner's five zones, three are recognized in the Claiborne. These are the *Reticulofenestra umbilica – Sphenolithus furcatolithoides* Zone, *Pemma papillatum* Zone, and the *Helicopontosphaera compacta – Chiasmolithus grandis* Zone. The *Discoaster tani* s. l. – *Sphenolithus radians* Zone cannot be recognized in the Claiborne since the lowest coccolithophore-bearing sediment in the Tallahatta has abundant *Reticulofenestra umbilica* (Levin), thus placing it in the P11 zone. *Bramletteius serraculoides* Gartner is an open ocean form and there is only one questionable occurrence in the hemipelagic sediments at Little Stave Creek. Therefore, this zone is not identifiable.

N. J. Tartamella of Chevron Oil Company is familiar with the Gulf Coast Eocene. He examined Bandy's foraminiferal range chart and agreed that the upper Lisbon and Gosport formations are in Blow's P14 zone. The base of the Lisbon Formation has previously been identified as the base of the P11 zone using the oyster *Ostrea lisbonensis*. The foraminifers in the Tallahatta are long-ranging species and could not help to resolve the proper placement of the Tallahatta. For the purpose of this paper, the upper Tallahatta is placed in the P11 zone.

Several species of calcareous nannofossils at Little Stave Creek have longer ranges than those indicated by previous authors. Upward extension of extinction levels may be due to reworking, but lowest occurrences were also extended downward. *Daktylethra punctulata* Gartner has previously been restricted to the *Pemma papillatum* Zone, but at Little Stave Creek it extends down into the *Reticulofenestra umbilica – Sphenolithus furcatolithoides* Zone (P11) and up into the *Helicopontosphaera compacta – Chiasmolithus grandis* Zone (P14). *Chiasmolithus solitus* (Bramlette and Sullivan) and *Campylosphaera dela* (Bramlette and Sullivan) have longer ranges in Alabama than indicated previously.

The middle Eocene calcareous nannofossil assemblage at Little Stave Creek is both abundant and diverse. Some samples contain as many as 60 species. Assemblages from open ocean sediments, however, include fewer species and lack entirely many diagnostic forms which are present in nearshore deposits. Middle Eocene sediments collected by the Deep Sea Drilling Project and examined by Bukry usually contain fewer than 20 species (JOIDES reports, Legs 1-8). Bukry, *et al.*, 1971, in a comparison of oceanic and nearshore assemblages list 22 oceanic species and 44 nearshore species. Twenty species are restricted to the hemipelagic realm. The widespread abundance of these provincial forms in the middle Eocene nearshore deposits throughout the world offers the potential for an even closer zonation than is possible for open ocean sediments. The ultimate goal indicated is separate zonations for these two environments incorporating cosmopolitan species wherever possible and, then, refinements made using provincial forms.

IX. CONCLUSIONS

Sediments of the Claiborne Group at Little Stave Creek contain a rich assemblage of coccolithophores with many representatives of the forms which are normally restricted to hemipelagic sediments and hence

not usable for zoning oceanic pelagic ooze. But provincialism among these forms is quite different from that commonly understood for other provincial groups. The difference is that, although restricted to shelf or inland seas in any single area, the same "provincial" forms are found in hemipelagic sediments on all continents. Thus, when applied to biostratigraphy, the same markers are used whether the section to be dated is in Europe or North America. Though the cosmopolitan coccoliths are indeed very abundant and useful in oceanic deposits, the sediments along the margins of continents generally contain better developed assemblages of pentaliths, rhabdoliths, discoliths, holococcoliths, and other similarly restricted forms, and the usefullness of these can by no means be ignored. They offer a potential for a finer zonation than is possible for sediments deposited in the open ocean.

X. ACKNOWLEDGEMENTS

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XI. SYSTEMATIC PALEONTOLOGY

Kingdom PLANTAE

Class HAPTOPHYCEAE
Christensen 1962

Order PYRMNESIALES
Christensen 1962

Family BRAARUDOSPHAERACEAE
Deflandre 1947

Genus BRAARUDOSPHAERA
Deflandre 1947

Type species: *Braarudosphaera bigelowi* (Gran and Braarud)

BRAARUDOSPHAERA BIGELOWI
(Gran and Braarud)

Plate 7, Figures 1-3

Pontosphaera bigelowi GRAN and BRAARUD, 1935, text-fig. 67; Recent Atlantic.

Braarudosphaera bigelowi (Gran and Braarud). DEFLANDRE, 1947, text-figs. 1-5; Recent, Atlantic. DEFLANDRE *in* GRASSÉ, 1952, figs. 358-C,D; figs. 362-P-R; Eocene, France. KLUMPP, 1953, pl. 16, figs. 1-2; text-figs. 2-1, 2-4; Eocene, Germany. BRAMLETTE and RIEDEL, 1954, pl. 38, fig. 6. DEFLANDRE and FERT, 1954, pl. 10, figs. 8-13; pl. 13, figs. 7-9. GARDET, 1955, in part; pl. 7, fig. 64; Neogene, Atlantic. MARTINI, 1958, pl. 2, fig. 6; Eocene, Germany. MANIVIT, 1959, in part; pl. 4, fig. 1; Eocene, Algeria. STRADNER, 1959b, text-figs. 63, 68. BÁLDI-BEKE, 1960, p. 14, fig. 8; Miocene, Hungary. MARTINI, 1960, pl. 8, fig. 1; Oligocene, Germany. BRAMLETTE and SULLIVAN, 1961, pl. 8, figs. 1-5; Eocene, California. MARTINI, 1961c, text-figs. 1-4, 6; Eocene-Oligocene, Germany. STRADNER and PAPP, 1961, pl. 37, figs. 1-3; text-fig. 22; Eocene, Mexico. LEVIN, 1965, pl. 42, figs. 4-5; Eocene, Mississippi. LOCKER, 1965, pl. 2, fig. 3; Eocene, Germany. GARTNER and SMITH, 1967, pl. 9, figs. 1-3; Eocene, Louisiana. HAY and MOHLER, 1967, pl. 202, figs. 12, 16, 20; Eocene, France. LEVIN and JOERGER, 1967, pl. 3, fig. 5; Eocene, Alabama. BLACK, 1968, pl. 147, fig. 5; Eocene, Mississippi. HAQ, 1968, pl. 11, figs. 3-4; Eocene, Germany. BYSTRICKÁ, 1969, pl. 63, fig. 14; Paleogene, Czechoslovakia. MARTINI, 1969b, pl. 27, figs. 9-10; Miocene, Africa. IACCARINO and FOLLINI, 1970, pl. 40, fig. 10; Cretaceous-Paleocene, Italy. BLACK, 1971, pl. 45.3, fig. 24; Eocene, England. HAQ, 1971a, pl. 6, fig. 3; Eocene, Pakistan. HAQ, 1971b, pl. 5, fig. 13; pl. 11, fig. 6; Oligocene, Germany. BLACK, 1972, pl. 93, figs. 3-4; Eocene, Mississippi, England. BYBELL and GARTNER, 1972, pl. 1, figs. 1-2; Eocene, Alabama. LOCKER, 1972, pl. 12, figs. 3-4.

Braarudosphaera bigelowi (Gran and Braarud). BOUCHÉ, 1962, pl. 4, figs. 1-5; Eocene, France.

Braarudosphaera bigelowi parvula Stradner. BOUCHÉ, 1962, pl. 4, fig. 9; Eocene, France.

Braarudosphaera discula Bramlette and Riedel. BYSTRICKÁ, 1969, pl. 63, fig. 13; Paleogene, Czechoslovakia.

Remarks: This common, easily identified species has, unlike most pentaliths, a considerable size range in any one locality. Samples containing pentaliths will generally include specimens of *B. bigelowi.*

Occurrence: B. bigelowi occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

BRAARUDOSPHAERA DISCULA
Bramlette and Riedel 1954

Braarudosphaera discula BRAMLETTE and RIEDEL, 1954, pl. 38, fig. 7; Eocene, Cuba. STRADNER, 1959b, text-fig. 64; Paleocene, Austria. BRAMLETTE and SULLIVAN, 1961, pl. 8, figs. 6-7; Eocene, California. Not STRADNER, 1961, text-fig. 43. BENEŠOVÁ and HANZLÍKOVÁ, 1962, pl. 4, figs. 6-7; Eocene, Czechoslovakia. Not STRADNER, 1962a, pl. 2, fig. 13. SULLIVAN, 1964, pl. 8, fig. 2; Paleocene, California. SULLIVAN, 1965, pl. 8, fig. 1; Eocene, California. HAY and MOHLER, 1967, pl. 202, figs. 13-15; Eocene, France. Not BYSTRICKÁ, 1969, pl. 63, fig. 13. BLACK, 1972, pl. 93, fig. 2; Eocene, France. SHERWOOD, 1974, pl. 6, fig. 12; Eocene, Texas.

Braarudosphaera bigelowi (Gran and Braarud). MANIVIT, 1959, pl. 4, fig. 2; Eocene, Algeria.

Braarudosphaera cf. *B. discula* Bramlette and Riedel. STRADNER and PAPP, 1961, pl. 37, fig. 5; Eocene, Austria. BILGÜTAY, *et al.,* 1969, pl. 3, fig. 16; Eocene, France. HAQ, 1971c, pl. 17, fig. 3; Oligocene, Syria.

Remarks: The few specimens of *B. discula* observed in the Little Stave Creek area agree well with other illustrated examples. *B. discula* is thinner than *Braarudosphaera rosa* Levin and Joerger, and has a more nearly circular outline. Both of these species have curved sutures, unlike the straight sutures of *Braarudosphaera irregularis* Bybell and Gartner.

Occurrence: B. discula occurs in the middle Eocene (Blow's P12-P14) of Alabama.

BRAARUDOSPHAERA IRREGULARIS
Bybell and Gartner 1972

Plate 7, Figure 4

Micrantholithus flos Deflandre. STRADNER and PAPP, 1961, in part; pl. 39, fig. 4.

Braarudosphaera irregularis BYBELL and GARTNER. 1972, pl. 1, figs. 3-4; Eocene, Alabama.

Remarks: B. irregularis differs from *Braarudosphaera discula* Bramlette and Riedel in having a crenulate rather than a smooth margin, a less circular outline, and straight rather than curved sutures.

Occurrence: B. irregularis occurs in the upper middle Eocene (Blow's P14) of Alabama.

BRAARUDOSPHAERA CHELOMA
Bybell and Gartner 1972

Plate 7, Figure 5

Braarudosphaera cheloma BYBELL and GARTNER, 1972, pl. 1, figs. 5-6; Eocene, Alabama.

Remarks: B. cheloma differs from *Braarudosphaera bigelowi* (Gran and Braarud) in having notches in its outline. This species has straight sides, unlike the lobate outer margin of each segment of *Micrantholithus concinnus* Bramlette and Sullivan.

Occurrence: B. cheloma occurs in the upper middle Eocene (Blow's P14) of Alabama.

BRAARUDOSPHAERA cf. B. ROSA
Levin and Joerger 1967

Plate 7, Figure 6

Braarudosphaera rosa LEVIN and JOERGER, 1967, pl. 3, figs. 6-7; Oligocene, Alabama. Not LOCKER, 1972, pl. 12, figs. 5-6.

Braarudosphaera cf. *B. rosa* Levin and Joerger. BYBELL and GARTNER, 1972, pl. 1, figs. 13-14; Eocene, Alabama.

Remarks: Specimens from the Little Stave Creek area closely resemble those of *B. rosa* with a rounded, lobate outline and irregular surface markings. The Eocene specimens are moderately thick and each segment tapers with increasing height, a characteristic not mentioned in the original description. This form is thicker than *Braarudosphaera discula* Bramlette and Riedel and has a more lobate outline.

Occurrence: Braarudosphaera cf. *B. rosa* occurs in the upper middle Eocene (Blow's P14) of Alabama.

BRAARUDOSPHAERA STYLIFER
Troelsen and Quadros 1971
Plate 8, Figures 1-2

Braarudosphaera cf. *B. bigelowi* (Gran and Braarud). BOUCHÉ, 1962, pl. 4, fig. 3; Eocene, France.

Braarudosphaera stylifer TROELSEN and QUADROS, 1971, pl. 1, figs. 8-14; Eocene, Brazil.

Braarudosphaera orthia BYBELL and GARTNER, 1972, pl. 1, figs. 7-12; Eocene, Alabama.

Remarks: Although *B. stylifer* in plan view is similar to *B. bigelowi* (Gran and Braarud), most specimens of *B. stylifer* have a more irregular outline and rounded apices. In some specimens the sides of the pentagon are bowed inward slightly, unlike the straight sides of *B. bigelowi.* The great thickness of *B. stylifer* is a diagnostic feature, and in plan view both pentagonal ends can be viewed by over-focusing and under-focusing with the microscope. On specimens in which the smaller end has been broken off, the irregular fracture surface is visible.

Occurrence: B. stylifer occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

Genus MICRANTHOLITHUS
Deflandre 1950

Type species: *Micrantholithus flos* Deflandre

MICRANTHOLITHUS ALTUS
Bybell and Gartner 1972

Plate 11

Micrantholithus altus BYBELL and GARTNER, 1972, pl. 2, figs. 1-10; Eocene, Alabama.

Remarks: M. altus has three prominent terminal lobes and a base, but *Micrantholithus procerus* Bukry and Bramlette has only shallow, marginal indentations, or none at all, and lacks a base. *M. altus* varies in thickness, but *M. procerus* is always quite thick.

Occurrence: M. altus occurs in the middle Eocene (Blow's P12-P14) of Alabama.

MICRANTHOLITHUS ANGULOSUS
Stradner and Papp 1961

Plate 9, Figures 1-4

Micrantholithus flos angulosus STRADNER, 1959b, text-figs. 61-62.

Micrantholithus angulosus STRADNER and PAPP, 1961, pl. 39, figs. 1-2; Eocene, Mexico. BYBELL and GARTNER, 1972, pl. 2, figs. 11-14; Eocene, Alabama. Not LOCKER, 1972, pl. 12, figs. 9-10.

Remarks: Both *M. angulosus* and *Micrantholithus altus* Bybell and Gartner have varying thicknesses and a trilobate termination for each arm. The former, however, lacks the diagnostic base of *M. altus.*

Occurrence: M. angulosus occurs in the middle Eocene (Blow's P12-P14) of Alabama.

MICRANTHOLITHUS ORNATUS
Sullivan 1965

Plate 7, Figure 7

Micrantholithus ornatus SULLIVAN, 1965, pl. 8, fig. 7; Eocene, California. CHANG, 1969, pl. 1, fig. 12; Eocene, England, India. BÁLDI-BEKE, 1971, pl. 4, fig. 5; Eocene, Hungary. BYBELL and GARTNER, 1972, pl. 1, figs. 15-16; Eocene, Alabama. LOCKER, 1972, pl. 13, figs. 5-6; Eocene, Europe. SHERWOOD, 1974, pl. 7, figs. 5-6; Eocene, Texas.

Remarks: Occasional specimens of this species in the Little Stave Creek area agree closely with the type specimens and other illustrated examples.

Occurrence: M. ornatus occurs in the middle Eocene (Blow's P12-P14) of Alabama.

MICRANTHOLITHUS PROCERUS
Bukry and Bramlette 1969

Plate 9, Figures 5-8

Micrantholithus procerus BUKRY and BRAMLETTE, 1969, pl. 2, figs. 12-15; Eocene, France, Indian Ocean, Louisiana, Alabama, Mexico, Brazil, Blake Plateau. BYBELL and GARTNER, 1972, pl. 3, figs. 1-6; Eocene, Alabama. SHERWOOD, 1974, pl. 7, figs. 11-12; 15-16; Eocene, Texas.

Remarks: Most specimens of *M. procerus* at Little Stave Creek closely resemble those figured by Bukry and Bramlette (1969). A few specimens have narrower arms and no medial indentations, and some specimens may also have two shallow indentations at the tip of each arm. All specimens are thick and resemble a long tapering dome in side view. *M. procerus* has indentations which are very shallow or absent, but *Micrantholithus altus* Bybell and Gartner is characterized by three prominent terminal lobes. In side view these two species are difficult to differentiate with the light microscope, although the numerous peripheral incisions of *M. altus*

appear as grooves running from the base to the top of the specimen.

Occurrence: M. procerus occurs in the upper middle Eocene (Blow's P14) of Alabama.

MICRANTHOLITHUS VESPER
Deflandre 1954

Micrantholithus vesper DEFLANDRE *in* GRASSÉ, 1952, invalid. DEFLANDRE and FERT, 1954, pl. 13, fig. 17; text-figs. 115-116. MARTINI, 1958, pl. 1, fig. 3; Eocene, Germany. MANIVIT, 1959, pl. 4, fig. 4; Eocene, Algeria. STRADNER, 1959b, text-fig. 59; Eocene, Miocene, Austria. BÁLDI-BEKE, 1960, pl. 14, fig. 10; Miocene, Hungary. MARTINI, 1960, pl. 8, fig. 5; Oligocene, Germany. BRAMLETTE and SULLIVAN, 1961, pl. 9, fig. 10; Eocene, California. MARTINI, 1961a, in part; pl. 1, fig. 9; Eocene, France. STRADNER and PAPP, 1961, pl. 39, figs. 5-6; Eocene, Austria, Mexico. Not BENEŠOVÁ and HANZLÍKOVÁ, 1962, pl. 2, fig. 10; Miocene, Czechoslovakia. LOCKER, 1965, pl. 2, fig. 5; Eocene, Germany. SULLIVAN, 1965, in part; pl. 9, fig. 4, 6-7; Eocene, California. HAY, MOHLER, and WADE, 1966, pl. 12, fig. 4; Eocene, USSR. HAY and MOHLER, 1967, pl. 202, figs. 17-19; Eocene, France. HAQ, 1968, pl. 7, fig. 11; Eocene, Germany. LOCKER, 1968, pl. 2, fig. 11; Eocene, Germany. PERCH-NIELSEN, 1971b, pl. 56, fig. 8; Eocene, Denmark. BRATU and GHETA, 1972, pl. 4, fig. 45; Eocene, Czechoslovakia. BYBELL and GARTNER, 1972, pl. 5, figs. 14-15; Eocene, Alabama. LOCKER, 1972, pl. 13, figs. 9-11; Eocene, Europe.

Micrantholithus cf. *M. vesper* Deflandre. BRAMLETTE and RIEDEL, 1954, pl. 38, fig. 8; Eocene, California.

Remarks: Disarticulated specimens of *M. vesper* are common at Little Stave Creek. The ray ends are often broken off and specimens with uniformly broken rays may be confused with *Micrantholithus flos* Deflandre.

Occurrence: M. vesper occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

Genus PEMMA Klumpp 1953
Type species: *Pemma rotundum* Klumpp

PEMMA BALIUM Bybell and Gartner 1972
Plate 8, Figures 3-5

Pemma balium BYBELL and GARTNER, 1972, pl. 4, figs. 7-9; Eocene, Alabama.

Remarks: In *P. balium* the sutural thickenings do not extend all the way to the periphery and there is no continuous rim. *Micrantholithus altus* Bybell and Gartner also has a base, but it is less developed and the arms of this species extend completely to the periphery. The flattened margin of one segment also distinguishes *P. balium* from similar species.

Occurrence: P. balium occurs in the middle Eocene (Blow's P11-P14) of Alabama.

PEMMA BASQUENSE BASQUENSE
(Martini) 1959b
Plate 10, Figures 1-5

Micrantholithus basquensis MARTINI, 1959b, in part; pl. 1, figs. 9-10; 12; Eocene, France. MARTINI, 1960, pl. 8, fig. 2; Oligocene, Germany. MARTINI, 1961a, pl. 5, fig. 46; Eocene, France. SULLIVAN, 1965, pl. 8, figs. 4-5; Eocene, California. SALES, 1966, pl. 6, fig. 4; LEVIN and JOERGER, 1967, pl. 3, fig. 10; Eocene-Oligocene, Alabama. BILGÜTAY, *et al.*, 1969, pl. 5, figs. 1-4; Eocene, France. BUKRY and KENNEDY, 1969, figs. 4-6; Eocene, California. PERCH-NIELSEN, 1971b, pl. 56, fig. 1; Eocene, Denmark.

Micrantholithus basquensis basquensis Martini. BOUCHÉ, 1962, pl. 2, fig. 11; Eocene, France.

Pemma snavelyi BUKRY and BRAMLETTE, 1969, in part; pl. 2, figs. 16-18; Eocene, Louisiana, Alabama, Oregon.

Pemma basquensis (Martini). BÁLDI-BEKE, 1971, in part; pl. 4, figs. 11-14; Eocene, Hungary.

Pemma stradneri (Chang). PERCH-NIELSEN, 1971b, pl. 56, figs. 2-3; Eocene, Denmark.

Pemma rotundum Klumpp. PERCH-NIELSEN, 1971b, pl. 56, figs. 5-6; Eocene, Denmark.

Pemma basquense basquense (Martini). BYBELL and GARTNER, 1972, pl. 3, figs. 7-14; Eocene, Alabama. Not SHERWOOD, 1974, pl. 7, figs 19-20.

Remarks: In *P. basquense basquense* the apices of the pentalith are located midway between the sutures, but the apices of *Pemma stradneri* (Chang) coincide with the sutures. The outline of *P. basquense basquense* is sharp and distinct, but that of *P. stradneri* is indistinct due to the slightly different locations for the marginal projections at various levels on the pentalith.

Occurrence: P. basquense basquense occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

PEMMA BASQUENSE CRASSUM (Bouché) 1962
Plate 10, Figures 6-9

Micrantholithus basquensis MARTINI, 1959b, in part; pl. 1, fig. 11; Eocene, France. MARTINI, 1960, pl. 8, fig. 7; Oligocene, Germany. BRAMLETTE and SULLIVAN, 1961, pl. 8, figs. 14-15; Eocene, California. LOCKER, 1968, pl. 2, fig. 13; Eocene, Germany.

Pemma rotundum Klumpp. MARTINI, 1959b, pl. 1, fig. 7; Eocene, Germany.

Pemma angulatum MARTINI, 1959b, in part; pl. 1, fig. 3; Eocene, Germany. MARTINI, 1960, pl. 8, fig. 7; Oligocene, Germany. LOCKER, 1972, pl. 13, fig. 13; Eocene, Europe.

Micrantholithus basquensis crassus BOUCHÉ, 1962, pl. 2, figs. 3,9-10; Eocene, France.

Micrantholithus parisiensis parisiensis Bouché. BUKRY and KENNEDY, 1969, fig. 4-8; Eocene, California.

Pemma basquensis (Martini). BÁLDI-BEKE, 1971, in part; pl. 5, figs. 1-2; pl. 4, fig. 9; Eocene, Hungary.

Pemma basquense crassum (Bouché). BYBELL and GARTNER, 1972, pl. 4, figs. 1-6; Eocene, Alabama. SHERWOOD, 1974, pl. 7, figs. 13-14; pl. 8, figs. 2-3; Eocene, Texas.

Micrantholithus angulosus Stradner and Papp. LOCKER, 1972, pl. 12, figs. 9-10; Eocene, Europe.

Pemma bulbosus (Bouché). SHERWOOD, 1974, pl. 7, figs. 17-18; pl. 8, fig. 8; Eocene, Texas.

Pemma major(Bouché). SHERWOOD, 1974, pl. 7, figs. 23-24; Eocene, Texas.

Remarks: P. basquense crassum includes thin, subcircular pentaliths with a discontinuous margin, formed by incisions occurring midway between sutures. The five sutural arms are of varying width and have lateral extensions along the margin which do not overlap and commonly do not touch. Some intermediate forms may be found between this subspecies and *Pemma basquense basquense* (Martini) in which one or more of the lateral, sutural extensions overlap.

Occurrence: P. basquense crassum occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

PEMMA PAPILLATUM Martini 1959a

Pemma papillatum MARTINI, 1959a, text-fig. 1; Eocene, Louisiana, California, Atlantic. STRADNER, 1959b, text-figs. 67, 69; Eocene, Mexico, France. MARTINI, 1961a, pl. 2, fig. 15; Eocene, France. STRADNER and PAPP, 1961, in part; pl. 38, fig. 4-6; Eocene, Mexico. LEVIN, 1965, pl. 42, figs. 7-8; Eocene, Mississippi. GARTNER and SMITH, 1967, pl. 10, figs. 1-3; Eocene, Louisiana. LEVIN and JOERGER, 1967, pl. 3, fig. 11; Eocene, Alabama. BLACK, 1968, pl. 147, fig. 6; Eocene, Mississippi. BÁLDI-BEKE, 1971, pl. 5, figs. 2-3; Eocene, Hungary. BLACK, 1971, pl. 45.3, fig. 25; Eocene, England. HAQ, 1971a, pl. 6, figs. 5-7; pl. 7, figs. 3-4; pl. 8, figs. 2, 4-5; Eocene, Pakistan. BLACK, 1972, pl. 94, figs. 3-4; Eocene, England. BYBELL and GARTNER, 1972, pl. 1, figs. 17-20; Eocene, Alabama. LOCKER, 1972, pl. 13, fig. 14; Eocene, Europe. SHERWOOD, 1974, pl. 7, figs. 21-22; pl. 8, fig. 5; Eocene, Texas.

Micrantholithus floridus CHANG, 1969, pl. 2, figs. 9-11; Eocene, England, India.

Remarks: The knobs along the periphery are diagnostic for this species and facilitate identification even when only a few knobs are present. Identification is often difficult, however, when all of the knobs are missing. The irregular outline, shallow marginal indentations, and a central depression in each segment of *Micrantholithus floridus* Chang indicate that it belongs in the species *P. papillatum.*

Occurrence: P. papillatum occurs in the middle Eocene (Blow's P12-P14) of Alabama.

PEMMA ROTUNDUM Klumpp 1953

Pemma rotundum KLUMPP, 1953, in part; text-figs. 2-3; pl. 16, fig. 3; Eocene, Germany. MARTINI, 1958, pl. 2, fig. 7; Eocene, Germany. MARTINI, 1959b, in part; pl. 1, fig. 6; Eocene, France. STRADNER, 1959b, text-fig. 66; Eocene, Austria. Not MARTINI, 1960, pl. 8, fig. 6. STRADNER and PAPP, 1961, pl. 38, fig. 1; Eocene, Austria. HAY and TOWE, 1962, figs. 4-5; Eocene, France. LOCKER, 1965, pl. 2, fig. 6; Eocene, Germany. SALES, 1966, pl. 6, fig. 5. BÁLDI-BEKE, 1971, pl. 4, fig. 10; Eocene, Hungary. HAQ, 1971a, pl. 7, fig. 10; Eocene, Pakistan. Not PERCH-NIELSEN, 1971b, pl. 56, figs. 5-6. BLACK, 1972, pl. 95, figs. 1-3; Eocene, Britain.

Braarudosphaera sp. STRADNER, 1961, text-fig. 43.

Micrantholithus parisiensis major BOUCHÉ, 1962, pl. 2, figs. 17, 19-21, 25; Eocene, France. CHANG, 1969, pl. 1, figs. 19-20; Eocene, England, India.

Remarks: P. rotundum and occasional circular forms of *Pemma serratum* (Chang) are similar. *P. rotundum* is larger and thinner and has a greater number of irregular periph-

eral crenulations and a more nearly circular outline. In cross-polarized light *P. rotundum* commonly shows a rim which is not found on *P. serratum.* At Little Stave Creek these two species do not occur together. The circular varieties of *P. serratum* may be an intermediate form between *P. rotundum* and the pentagonal forms of *P. serratum.*

Occurrence: P. rotundum occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

PEMMA SERRATUM (Chang) 1969
Plate 12, Figures 1-6

Micrantholithus serratus CHANG, 1969, pl. 1, figs. 5-6, 15-16; Eocene, England, India.

Pemma serratum (Chang). BYBELL and GARTNER, 1972, pl. 5, figs. 5-13; Eocene, Alabama.

Remarks: The margin of *P. serratum* is not as well defined as that of *Pemma basquense basquense* (Martini) because the crenulations have a different spacing in the several layers that make up the pentalith, while in *P. basquense basquense* the crenulations are aligned. In *P. serratum* the apices of the pentagon coincide with the sutures, but in *P. basquense basquense* the apices are located between the sutures.

Occurrence: P. serratum occurs in the upper middle Eocene (Blow's P14) of Alabama.

PEMMA STRADNERI (Chang) 1969
Plate 12, Figures 7-8

Pemma snavelyi BUKRY and BRAMLETTE, 1969, in part; pl. 2, fig. 19; Eocene, Louisiana, Alabama, Oregon.

Micrantholithus stradneri CHANG, 1969, pl. 1, figs. 1-4; Eocene, England, India.

Pemma stradneri (Chang). Not PERCH-NIELSEN, 1971b, pl. 56, figs. 2-3. BYBELL and GARTNER, 1972, pl. 5, figs. 1-4; Eocene, Alabama.

Pemma basquense basquense (Martini). SHERWOOD, 1974, pl. 7, figs. 19-20; Eocene, Texas.

Remarks: Most specimens of *P. stradneri* from the Little Stave Creek area agree closely with those figured by Chang (1969) and by Bukry and Bramlette (1969). A few specimens have a distinct double projection between the sutures due to the incomplete overlap of adjacent sutural thickenings. *P. stradneri* is similar to *Pemma serratum* (Chang) and they probably are closely related. *P. stradneri* has more prominent extensions at the apices of the pentagon than *P. serratum,* but their basic structures seem to be similar.

Occurrence: P. stradneri occurs in the middle Eocene (Blow's P12-P14) of Alabama.

PEMMA sp. A
Plate 7, Figure 8

Remarks: In this form the apices of the pentagon coincide with the intersection of the sutures and the margin. The sides of the pentagon are nearly straight and tend to bow inward slightly. Each segment has a very small circular pore halfway between the center and the margin and quite close to a suture line. Specimens are somewhat thicker at the suture and the center, thinning toward the margin and between sutures. This species is similar in outline to *Micrantholithus flos* Deflandre, but the latter lacks the small pores, has a more localized thickening near the sutures, and a more irregular periphery.

Occurrence: Pemma sp. A occurs in the upper middle Eocene (Blow's P14) of Alabama.

Genus PENTASTER Bybell and Gartner
Type species: *Pentaster lisbonensis*
Bybell and Gartner

PENTASTER LISBONENSIS
Bybell and Gartner 1972
Plate 13, Figures 1-2

Pentaster lisbonensis BYBELL and GARTNER, 1972, pl. 4, figs. 10-14; Eocene, Alabama.

Remarks: This distinctive and ornate species has no known close relative among the Braarudosphaeraceae and is always easily indentified.

Occurrence: P. lisbonensis occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

Family COCCOLITHACEAE Kamptner 1928
Genus CAMPYLOSPHAERA Kamptner 1963
Type species: *Campylosphaera bramletti*
Kamptner

CAMPYLOSPHAERA DELA
(Bramlette and Sullivan) 1961
Plate 14, Figures 4-6

Coccolithites delus BRAMLETTE and SULLIVAN, 1961, pl. 7, figs. 1-2; Paleocene-Eocene, California. SULLIVAN, 1964, pl. 1, figs. 8-9; Paleocene, California.

Coccolithites aff. *C. delus* BRAMLETTE and SULLIVAN, 1961, pl. 7, figs. 3-4; Eocene, California. SULLIVAN, 1964, pl. 1, figs. 7; Paleocene, California.

Cyathosphaera crux (Deflandre and Fert). HAY and TOWE, 1962, pl. 2, fig. 1; Eocene, France.

Coccolithus delus (Bramlette and Sullivan). HAQ, 1967, pl. 6, fig. 7; Eocene, Pakistan. PERCH-NIELSEN, 1967, pl. 1, figs. 1-3; Eocene, Denmark.

Campylosphaera dela (Bramlette and Sullivan). HAY and MOHLER, 1967, pl. 198, fig. 14; Paleocene, France. BUKRY and KENNEDY, 1969, fig. 3-1; Eocene, California.

Genus ind. sp. *delus* (Bramlette and Sullivan). REINHARDT, 1967, pl. 2, fig. 16; Eocene, Germany.

Cruciplacolithus delus (Bramlette and Sullivan). PERCH-NIELSEN, 1971b, pl. 13, figs. 7-8; Eocene, Denmark. PERCH-NIELSEN, 1972, pl. 4, fig. 2; Paleocene, Atlantic. SHERWOOD, 1974, pl. 2, figs. 9-10; pl. 3, figs. 7-10; Eocene, Texas.

Chiasmolithus delus (Bramlette and Sullivan). LOCKER, 1972, pl. 9, fig. 2; Paleocene, Europe.

Remarks: C. dela has a large open central area with two crossbars, one aligned with the long axis and the other aligned with the short axis of the shields. The proximal shield forms a broad square arch and the transverse axis serves as the axis of curvature. The distal shield similarly bends along the transverse axis, but it also arches in the opposite direction along the longitudinal axis. *C dela* and *Campylosphaera eodela* Bukry and Percival have similar shield constructions, but *C. dela* is larger, has a more rectangular outline and a larger central area.

Occurrence: C. dela occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

Genus CHIASMOLITHUS
Hay, Mohler, and Wade 1966
Type species: *Tremalithus oamaruensis* Deflandre

CHIASMOLITHUS GRANDIS
(Bramlette and Riedel) 1954
Plate 23, Figure 3

"coccolith" JUKES-BROWN and HARRISON, 1892, text-fig. 7.

Coccolithus cretaceus DEFLANDRE *in* GRASSÉ, 1952, text-fig. 360D; Eocene, France.

Coccolithus grandis BRAMLETTE and RIEDEL, 1954, pl. 38, fig. 1; Eocene, Barbados, California. DEFLANDRE and FERT, 1954, text-fig. 48; Eocene, France. BRAMLETTE and SULLIVAN, 1961, pl. 2, figs. 1-3; Eocene, California. BACHMANN, PAPP and STRADNER, 1963, pl. 23, figs. 1-3; Austria. BYSTRICKÁ, 1963, pl. 1, figs. 4-6; Eocene, Czechoslovakia. SULLIVAN, 1964, pl. 2, figs. 1-2; Paleocene, California.

Coccolithos cf. *C. grandis* Bramlette and Riedel. BENEŠOVÁ and HANZLÍKOVÁ, 1962, pl. 4, fig. 11; Eocene, Czechoslovakia.

Chiasmolithus grandis (Bramlette and Riedel). RADOMSKI, 1968, pl. 44, figs. 3-4; Paleocene-Eocene, Poland. BILGÜTAY, *et al.*, 1969, pl. 2, figs. 3-4; Eocene, France. BUKRY and KENNEDY, 1969, fig. 3-2; Eocene, California. GARTNER, 1970, fig. 11-3; fig. 14; Eocene. BÁLDI-BEKE, 1971, pl. 3, figs. 1,4; Eocene, Hungary. BUKRY, 1971, pl. 5, fig. 5; Eocene, Pacific. PERCH-NIELSEN, 1971b, pl. 9, figs. 1-2; pl. 10, fig. 4; pl. 60, figs. 1-2; Eocene, Denmark. BRATU and GHETA, 1972, pl. 2, figs. 16-17; Paleocene-Eocene, Czechoslovakia. LOCKER, 1972, pl. 9, figs. 1-2; Eocene, Europe. PERCH-NIELSEN, 1972, pl. 3, fig. 4; Eocene, Atlantic. SHERWOOD, 1974, pl. 3, figs. 1-2; Eocene, Texas.

Chiasmolithus expansus (Bramlette and Sullivan). PERCH-NIELSEN, 1971b, pl. 9, fig. 3; Eocene, Denmark.

Remarks: This large distinctive species has toothlike projections which extend into the central opening between the crossbars. These bars resemble two broad U's which have a common base. There is a fine grillwork in the central opening that on many specimens is partially or completely broken out. This grillwork is visible only with the electron microscope.

Occurrence: C. grandis occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

CHIASMOLITHUS SOLITUS
(Bramlette and Sullivan) 1961

Plate 14, Figures 1-2

Coccolithus solitus BRAMLETTE and SULLIVAN, 1961, pl. 2, fig. 14; Eocene, California. SULLIVAN, 1964, pl. 1, fig. 13; Paleocene, California.

Chiasmolithus solitus (Bramlette and Sullivan). Not LOCKER, 1967, pl. 1, figs. 5-6. RADOMSKI, 1968, pl. 45, figs. 13-14; Paleocene-Eocene, Poland. GARTNER, 1970, fig. 16; Eocene. BÁLDI-BEKE, 1971, pl. 3, figs. 2-3; Eocene, Hungary. MARTINI, 1971a, pl. 2, figs. 10-11; Eocene. PERCH-NIELSEN, 1971b, pl. 11, fig. 1; pl. 12, fig. 1-5; pl. 13, fig. 5; pl. 14, fig. 11; pl. 60, figs. 19-20; Oligocene, Denmark. LOCKER, 1972, pl. 9, figs. 3-4; Eocene, Europe. SHERWOOD, 1974, pl. 1, figs. 15-16; Eocene, Texas.

Remarks: The central arm of *C. solitus* is spanned by an X-shaped structure which is formed by two S-shaped bars. *Chiasmolithus bidens* (Bramlette and Sullivan) is similar, cut lacks the diagnostic curve to the crossbars.

Occurrence: C. solitus occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

CHIASMOLITHUS TITUS Gartner 1970
Plate 14, Figure 3

Coccolithus consuetus Bramlette and Sullivan. LEVIN and JOERGER, 1967, pl. 1, fig. 1; Eocene, Alabama.

Chiasmolithus titus GARTNER, 1970, fig. 17; Eocene. SHERWOOD, 1974, pl. 1, figs. 19-20; Eocene, Texas.

Remarks: In *C. titus* the central area is spanned by two crossbars which form an "X." One bar is straight and diagonal across the area and the other bar is S-shaped. This species is somewhat smaller than most species of the genus and the shape of the crossbar is diagnostic.

Occurrence. C. titus occurs in the middle Eocene (Blow's P11-P14) of Alabama.

Genus COCCOLITHUS Schwarz 1894
Type species: *Coccolithus oceanicus* Schwarz

COCCOLITHUS CRASSIPONS Bouché 1962
Plate 22, Figure 6

Coccolithus crassipons BOUCHÉ, 1962, pl. 1, fig. 14; text-fig. 3; Eocene, France. LOCKER, 1972, pl. 6, figs. 5-6; Eocene, Europe.

Coccolithus staurion Bramlette and Sullivan. REINHARDT, 1967, pl. 4, fig. 3; Eocene, Germany.

Remarks: C. crassipons is similar to *Birkelundia jugata* (Perch-Nielsen), but the latter has a larger central opening and a straight crossbar, which is not distinct optically from the rest of the placolith.

Occurrence: C. crassipons occurs in the lower middle Eocene (Blow's P11) of Alabama.

COCCOLITHUS SARSIAE Black 1962
Plate 15, Figure 6

Coccolithus sarsiae BLACK, 1962, pl. 8, fig. 2; pl. 9, figs. 2-6; Upper Tertiary, Atlantic. HAY, MOHLER, and WADE, 1966, pl. 1, figs. 2-5; Eocene, USSR. CLOCCHIATTI, 1971, pl. 3, fig. 2; Miocene-Pliocene, Africa, SHERWOOD, 1974, pl. 1, figs. 5-7; pl. 2, fig. 3; Eocene, Texas.

Coccolithus aff. *C. sarsiae* Black. IACCARINO and FOLLINI, 1970, not pl. 41, fig. 28.

Coccolithus cf. *C. sarsiae* BLACK, 1971, pl. 45.1 (6); Oligocene, Denmark.

Remarks: C. sarsiae has a narrow, elliptical central perforation. *Coccolithus pelagicus* (Wallich) normally has two small central perforations. There are fewer shield segments on *C. sarsiae* than on *C. pelagicus* and individual segments can be discerned with the light microscope. In phase contrast the distal shield is dark and distinct and it exhibits low birefringence in cross-polarized light.

Occurrence: C. sarsiae occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

COCCOLITHUS sp. A
Plate 22, Figure 7

Ericsoniá muiri (Black). SHERWOOD, in part; pl. 3, figs. 21-22; Eocene, Texas.

Remarks: In this species the distal and the proximal shield are almost the same size and the elliptical central area is large. Only the proximal shield and collar are bright in cross-polarized light and individual shield segments are visible with a light microscope. *Coccolithus* sp. A is similar to *Coccolithus pelagicus* (Wallich), but has a much larger central area and fewer shield segments.

Occurrence: Coccolithus sp. A occurs only in the upper middle Eocene (Blow's P14) of Alabama.

Genus CRUCIPLACOLITHUS Hay and Mohler 1967

Type species : *Heliorthus tenuis* Stradner

CRUCIPLACOLITHUS STAURION (Bramlette and Sullivan) 1961

Plate 20, Figure 7

Coccolithus staurion BRAMLETTE and SULLIVAN, 1961, pl. 2, figs. 5-6; Eocene, California, Texas, France. BENEŠOVÁ and HANZLÍKOVÁ, 1962, in part; pl. 3, fig. 3; Miocene, Czechoslovakia. SULLIVAN, 1964, pl. 3, figs. 2-3; Paleocene, California. SULLIVAN, 1965, pl. 3, fig. 7; Eocene, California. Not REINHARDT, 1967, pl. 4, fig. 3; Eocene, Germany.

Coccolithus aff. *C. staurion* Bramlette and Sullivan. HAQ, 1967, pl. 6, fig. 9; Eocene, Pakistan.

Coccolithus cf. *C. staurion* Bramlette and Sullivan. PERCH-NIELSEN, 1967, pl. 1, figs. 4-5, 12-13; Eocene, Denmark.

Chiasmolithus staurion (Bramlette and Sullivan). Not BUKRY and KENNEDY, 1969, figs. 3-3, 3-4. LOCKER, 1972, pl. 9, figs. 9-10; Eocene, Europe.

Cruciplacolithus staurion (Bramlette and Sullivan). GARTNER, 1971, Eocene, Blake Plateau. SHERWOOD, 1974, pl. 3, figs. 5-6; Eocene, Texas.

Birkelundia staurion (Bramlette and Sullivan). PERCH-NIELSEN, 1971b, pl. 15, figs. 1, 3-6; pl. 61, figs. 16-17; Eocene, Denmark.

Remarks: C. staurion is distinguished from other similar placoliths by its large size and very slender crossbars.

Occurrence: C. staurion occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

Genus CYCLOCOCCOLITHINA Wilcoxon 1970

Type species: *Coccosphaera leptoporas* Murray and Blackman

CYCLOCOCCOLITHINA FORMOSA (Kamptner) 1963

Plate 16, Figures 4-5

Cyathosphaera diaphragma HAY and TOWE, 1962, in part; pl. 6, figs. 2, 5-6; Eocene, France.

Cyclococcolithus formosus KAMPTNER, 1963, pl. 2, fig. 8, Eocene, Pacific. REINHARDT, 1966, pl. 21, fig. 8; Eocene, Germany. REINHARDT, 1967, pl. 1, figs. 3-4; 7-8; pl. 6, figs. 3, 6; Eocene, Germany. RADOMSKI, 1968, pl. 44, figs. 7-8; Eocene-Oligocene, Poland. MARTINI, 1969a, pl. 1, figs. 1-2; Oligocene, Switzerland. BÁLDI-BEKE, 1971, pl. 1, figs. 18-19; Eocene, Hungary. MARTINI, 1971a, pl. 3, figs. 1-2; Eocene-Oligocene. POZARYSKA and LOCKER, 1971, pl. 2, figs. 11-12; Eocene, Poland. ROTH, BAUMANN, and BERTOLINO, 1971, figs. 6-9. BRATU and GHETA, 1972, pl. 4, figs. 55-56; Eocene, Czechoslovakia. LOCKER, 1972, pl. 7, figs. 7-8; Eocene, Europe.

Coccolithus lusitanicus BLACK, 1964, pl. 50, figs. 1-2; Eocene, Atlantic.

Cyclococcolithus lusitanicus (Black). HAY, MOHLER, and WADE, 1966, pl. 7, figs. 3-6; Eocene, USSR. BRAMLETTE and WILCOXON, 1967, pl. 3, figs. 16-17; Eocene-Oligocene, Trinidad. BUKRY and KENNEDY, 1969, pl. 3, fig. 5; Eocene, California.

Cyclococcolithus annulatus REINHARDT, 1966, pl. 1, figs. 3-4; text-fig. 2; Eocene, Germany.

Cyclococcolithus orbis GARTNER and SMITH, 1967, pl. 4, figs. 1-3; Eocene, Louisiana.

Coccolithus diaphragma (Hay and Towe). HODSON and WEST, 1970, pl. 1, fig. 7; Eocene, England.

Ericsonia formosa (Kamptner). HAQ, 1971a, pl. 4, figs. 7-8; Eocene, Pakistan. HAQ, 1971b, in part; pl. 7, figs. 11-12; pl. 9, figs. 5-6; pl. 10, fig. 8; pl. 16, fig. 2; Eocene, Germany.

Ericsonia cf. *E. formosa* (Kamptner). HAQ, 1971a, pl. 1, fig. 1; pl. 4, fig. 6; pl. 5, figs. 11-12; Paleocene, Persia, Pakistan.

Ericsonia alternans Black. PERCH-NIELSEN, 1971b, pl. 1, figs. 9-11; Eocene, Denmark.

Cyclococcolithina formosa (Kamptner). SHERWOOD, 1974, pl. 1, figs. 21-22; pl. 4, fig. 2; Eocene, Texas.

Remarks: C. formosa has a wide collar and a small, circular central perforation. The collar and shield elements are joined distally along a serrate line. In cross-polarized light only the proximal shield is bright, a feature which distinguishes this species from other circular placoliths.

Occurrence: C. formosa occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

CYCLOCOCCOLITHINA RETICULATA (Gartner and Smith) 1967

Plate 16, Figures 1-3

Cyclococcolithus reticulatus GARTNER and SMITH, 1967, pl. 5, figs. 1-4; Eocene, Louisiana.

Cyclococcolithus cf. *C. reticulatus* Gartner and Smith. RADOMSKI, 1968, pl. 44, figs. 11-12; Eocene, Poland.

Cyclococcolithus neogammation Bramlette and Wilcoxon. BÁLDI-BEKE, 1971, in part; pl. 1, fig. 21; Eocene, Hungary.

Cribrocentrum reticulatum (Gartner and Smith). PERCH-NIELSEN, 1971b, pl. 25, figs. 4-9; Eocene, Denmark.

Reticulofenestra dictyoda dictyoda (Deflandre and Fert). LOCKER, 1972, pl. 8, figs. 1-2; Eocene, Europe.

Remarks: The central area of *C. reticulata* is pierced by numerous circular pores and has a distinctive pattern in cross-polarized light. The shield sutures are almost radial and overlap slightly. Each shield segment normally forms a point at the periphery of the shields. Pores on some specimens are slit-like, the slits radiating outward from the central area. *C. reticulata* is similar to *Reticulofenestra dictyoda* (Deflandre and Fert), but it has fewer segments per shield and fewer, more rounded perforations.

Occurrence: C. reticulata occurs in the middle Eocene (Blow's P11-P14) of Alabama.

Genus ERICSONIA Black 1964

Type species: *Ericsonia occidentalis* Black

ERICSONIA FENESTRATA (Deflandre and Fert) 1954

Plate 21, Figure 7

Discolithus fenestratus DEFLANDRE and FERT, 1954, pl. 11, fig. 25; text-fig. 52; Oligocene, New Zealand.

Ericsonia fenestrata (Deflandre and Fert). HAQ, 1968, in part; pl. 1, figs. 11-12; Eocene, Germany. STRADNER and EDWARDS, 1968, in part; pl. 10, fig. 4; pl. 11, figs. 1-4; Eocene, New Zealand. LOCKER, 1970, figs. 1-2; Paleocene-Eocene, Germany. ROTH, 1970, pl. 1, fig. 6; Oligocene, Alabama, Italy, Trinidad; Eocene, Italy. HAQ, 1971b, in part; pl. 3, fig. 9; Eocene, Germany. PERCH-NIELSEN, 1971b, in part; pl. 5, figs. 4-6; pl. 6, figs. 10-11; Eocene, Denmark.

Ericsonia? singularis PERCH-NIELSEN, 1971b, pl. 7, figs. 1-3, 5; Eocene, Denmark, Germany.

Ericsonia cf. *E. fenestrata* (Deflandre and Fert). PERCH-NIELSEN, 1971b, in part; pl. 6, figs. 1-2, 5; Eocene, Denmark.

Remarks: This placolith has more than two rows of numerous, small, circular pores in the central area and curved shield segments. Specimens with only one ring of pores belong in the species *Ericsonia subdisticha* (Roth and Hay) and *Ericsonia quadriperforata* Roth has only four pores.

Occurrence: E. fenestrata occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

Genus MARKALIUS Bramlette and Martini 1964

Type species: *Cyclococcolithus leptoporus* Murray and Blackman var. *inversus* Deflandre

MARKALIUS INVERSUS (Deflandre) 1954

Plate 15, Figure 7

Cyclococcolithus leptoporus var. *inversus* Deflandre. DEFLANDRE and FERT, 1954, in part; pl. 9, figs. 4-5; Oligocene, New Zealand.

Markalius inversus (Deflandre). EDWARDS, 1966, fig. 26; table 1. IACCARINO and FOLLINI, 1970, pl. 40, fig. 36; Cretaceous-Paleocene, Italy. MARTINI, 1971a, pl. 1, figs. 1-2, Cretaceous-Oligocene. PERCH-NIELSEN, 1971b, pl. 2, figs. 6-7; Eocene, Denmark. PERCH-NIELSEN, 1972, pl. 5, figs. 4, 6; Eocene, Atlantic.

Cyclococcolithus inversus (Deflandre). HAY, MOHLER, and WADE, 1966, pl. 7, fig. 2; Eocene, USSR. REINHARDT, 1967, pl. 1, figs. 9, 13; pl. 2, fig. 11; pl. 6, fig. 4; Eocene, Germany. HAQ, 1968, in part; pl. 8, fig. 1; Eocene, Germany. STRADNER and EDWARDS, 1968, pls. 26-27; Eocene, New Zealand. MARTINI, 1969b, pl. 1, figs. 3-4; Oligocene, Switzerland. HAQ, 1971b, pl. 9, figs. 1-3; pl. 18, figs. 3-4; Eocene, Germany. HAQ, 1971c, pl. 19, figs. 6, 8; Oligocene, Syria. LOCKER, 1972, pl. 7, fig. 4; Eocene, Europe.

Cyclococcolithus sp. LEVIN and JOERGER, 1967, pl. 1, figs. 10-11; Eocene, Alabama.

Markalius cf. *M. inversus* (Deflandre). BLACK, 1968, pl. 144, fig. 6; Cretaceous, Britain.

Cyclococcolithus astroporus Stradner. RADOMSKI, 1968, pl. 46, figs. 1-2; Eocene, Poland.

Remarks: M. inversus has curved distal shield segments, but the segments of the proximal shield are almost straight. Small, radiating wedge-shaped segments entirely fill the central area and in cross-polarized light these segments have an X-shaped extinction pattern which does not continue out onto the shield area. Gartner (1971) separates *Markalius inversus* and *Markalius astroporus* (Stradner) according to the number of shield segments. *M. inversus* has 27-18 elements per shield and Little Stave Creek specimens fall within this designation.

Occurrence: M. inversus occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

Genus RETICULOFENESTRA
Hay, Mohler, and Wade 1966
Type species: *Reticulofenestra caucasica* Hay, Mohler, and Wade

RETICULOFENESTRA BISECTA
(Hay, Mohler, and Wade) 1966
Plate 15, Figure 5

Syracosphaera bisecta HAY, MOHLER, and WADE, 1966, pl. 10, figs. 1-6; Eocene, USSR.

Coccolithus pseudocarteri HAY, MOHLER, and WADE, 1966, in part; pl. 2, figs. 2-4; Eocene, USSR.

Coccolithus bisectus (Hay, Mohler, and Wade). BRAMLETTE and WILCOXON, 1967, pl. 4, figs. 11-13; Oligocene, Trinidad. RADOMSKI, 1968, pl. 45, figs. 19-20; Eocene, Poland. BUKRY, 1971, pl. 5, fig. 2; pl. 6, fig. 1; Eocene, Pacific. CLOCCHIATTI, 1971, pl. 3, figs. 3-5; fig. 2; Eocene-Oligocene, Africa. PERCH-NIELSEN, 1972, pl. 6, figs. 4, 6; Oligocene, Atlantic.

Coccolithus stavensis LEVIN and JOERGER, 1967, pl. 1, fig. 7; Eocene-Oligocene, Alabama.

Stradnerius dictyodus (Deflandre and Fert). HAQ, 1968, in part; pl. 2, figs. 7-8; pl. 3, figs. 4-8; Eocene, Germany.

Reticulofenestra dictyoda (Deflandre and Fert). STRADNER and EDWARDS, 1968, in part; pl. 13, figs. 1-2; pl. 14, figs. 2-5; Eocene, New Zealand.

Dictyococcites dictyodus (Deflandre and Fert). MARTINI, 1969b, in part; pl. 1, figs. 5-6; pl. 4, fig. 40; Oligocene.

Reticulofenestra bisecta (Hay, Mohler, and Wade). ROTH, 1970, pl. 3, fig. 6; Oligocene. POZARYSKA and LOCKER, 1971, pl. 2, figs. 15-16; Eocene, Poland. LOCKER, 1972, pl. 8, figs. 5-6; Eocene, Europe.

Dictyococcites bisectus (Hay, Mohler, and Wade). BUKRY and PERCIVAL, 1971, pl. 2, figs. 12-13; Eocene-Oligocene, Gulf Coast, Europe, Atlantic, Pacific.

Reticulofenestra placomorpha (Kamptner). BRATU and GHETA, 1972, pl. 5, figs. 63-64; Eocene, Czechoslovakia.

Remarks: In this subcircular placolith the central area is filled with tabular crystals which radiate out from a medial line. In some specimens these crystals do not meet and there is a central slit or two small pores. The numerous shield segments overlap slightly and there is little or no bending along the suture lines. In cross-polarized light both shields and the central area are bright, the individual shield segments are not visible, and the extinction lines are somewhat obscure in the center of the placolith. In phase contrast, specimens are very dim, a typical feature of the genus *Reticulofenestra.*

Occurrence: R. bisecta occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

RETICULOFENESTRA CALLIDA
(Perch-Nielsen) 1971b n. comb.
Plate 21, Figure 8

Dictyococcites callidus PERCH-NIELSEN, 1971, pl. 22, figs. 1-4; pl. 23, fig. 3; pl. 61, figs. 30-31; Eocene, Denmark.

Reticulofenestra scissura Hay, Mohler, and Wade. HAQ, 1971b, in part; pl. 15, figs. 2-4; Oligocene, Germany.

Remarks: This placolith has a diagnostic elliptical knob in the central area. Slender radiating struts connect this knob to the collar. Each collar crystal merges into a strut such that they occur at several levels on the placolith. The distal shield has two separate layers of segments, one much smaller and above the other. Each shield segment forms a point at its periphery. In cross-polarized light the struts of the central area are visible and are distinctive for this species.

Occurrence: R. callida occurs in the upper middle Eocene (Blow's P14) of Alabama.

RETICULOFENESTRA HILLAE
Bukry and Percival 1971
Plate 15, Figure 4

Reticulofenestra hillae BUKRY and PERCIVAL, 1971, pl. 6, figs. 1-3; Eocene-Oligocene, Atlantic, Pacific, Gulf Coast.

Remarks: This elliptical placolith resembles *Reticulofenestra umbilica* (Levin), but is smaller and more uniformly-sized, with a thicker collar and a smaller central area. It possesses the typical *Reticulofenestra* extinction pattern in cross-polarized light and is dim in phase contrast.

Occurrence: R. hillae occurs in the upper middle Eocene (Blow's P14) of Alabama.

RETICULOFENESTRA UMBILICA
(Levin) 1965
Plate 15, Figures 1-3

Coccolithus sp. BOUCHE, 1962, pl. 1, figs. 17, 21-22; Eocene, France.

Coccolithus placomorphus (Kamptner). STRADNER, 1964, text-fig. 10; Eocene, Austria.

Coccolithus umbilicus LEVIN, 1965, pl. 41, fig. 2; Eocene, Mississippi. GARTNER and SMITH, 1967, pl. 1, figs. 3-4; pl. 2, figs. 1-3; Eocene, Louisiana.

Reticulofenestra caucasica HAY, MOHLER, and WADE, 1966, in part; pl. 3, figs. 1-2; pl. 2, fig. 5; pl. 4, figs. 1-2; Eocene, USSR. PERCH-NIELSEN, 1967, pl. 1, figs. 9-11; Eocene, Denmark.

Apertapetra samodurovi HAY, MOHLER, and WADE, 1966, in part; pl. 6, figs. 1-3; Eocene, USSR.

Apertapetra umbilicus (Levin). BRAMLETTE and WILCOXON, 1967, pl. 5, figs. 1-2; Oligocene, Trinidad. LEVIN and JOERGER, 1967, pl. 1, fig. 9; Eocene-Oligocene, Alabama. RADOMSKI, 1968, pl. 45, figs. 1-2; Eocene, Poland.

Coccolithus coenurus REINHARDT, 1967, pl. 2, figs. 2, 6; pl. 5, fig. 5; Eocene, Germany.

Coccolithus pelicomorphus REINHARDT, 1967, pl. 1, figs. 10-11; pl. 5, fig. 10; Eocene, Germany.

Reticulofenestra umbilica (Levin). MARTINI and RITZKOWSKI, 1968, pl. 1, figs. 11-12; Eocene, Germany. BUKRY, 1971, pl. 6, fig. 6; Eocene, Pacific. HAQ, 1971b, pl. 7, figs. 5-6; pl. 10, figs. 12-13; Eocene-Oligocene, Germany. MARTINI, 1971a, pl. 2, figs. 18-19; Eocene-Oligocene. PERCH-NIELSEN, 1971b, pl. 21, fig. 7; pl. 23, figs. 1-2; pl. 24, figs. 1-3; Eocene, Denmark. PERCH-NIELSEN, 1972, pl. 9, fig. 6; Eocene, Atlantic. SHERWOOD, 1974, pl. 3, figs. 3-4; Eocene, Texas.

Reticulofenestra placomorpha (Kamptner). STRADNER and EDWARDS, 1968, in part; pl. 19; pl. 20; pls. 23-24; pl. 25, figs. 1-2; Eocene-Miocene, New Zealand. LOCKER, 1972, pl. 8, figs. 7-8; pl. 17, fig. 5; Eocene.

Reticulofenestra cf. *R. umbilica* (Levin). Not HAQ, 1971c, pl. 13, figs. 13-14.

Ericsonia samodurovi (Hay, Mohler, and Wade). HAQ, 1971c, pl. 13, fig. 12; Oligocene, Syria.

Reticulofenestra samodurovi (Hay, Mohler, and Wade). LOCKER, 1972, pl. 17, figs. 4, 6; Eocene.

Remarks: This elliptical placolith has a large central area that is covered with a fine grid at the level of the proximal shield. The central part of the grid has numerous, small, circular pores, which elongate into slits near the margin. The numerous segments of each shield are indiscernible under the light microscope. The collar appears as a ring of overlapping, square elements on the distal shield. In cross-polarized light this species exhibits the typical *Reticulofenestra* extinction pattern: both shields and the collar exhibit birefringence. There is considerable size variation within this species.

Occurrence: R. umbilica occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

Family DISCOASTERACEAE Tan Sin Hok 1927

Genus DISCOASTER Tan Sin Hok 1927

Type species: *Discoaster pentaradiatus* Tan Sin Hok

DISCOASTER BARBADIENSIS Tan Sin Hok 1927

Plate 17, Figure 3

"Krystaldrusen" EHRENBERG, 1854, pl. 24, figs. 67; pl. 25, figs. 13-15.

"Crystalloids" JUKES-BROWN and HARRISON, 1892, text-figs. 4-6.

Discoaster barbadiensis TAN SIN HOK, 1927. BRAMLETTE and RIEDEL, 1954, pl. 39, fig. 5; Eocene, Barbados, California, Saipan. GARDET, 1955, pl. 7, fig. 68; Neogene, Algeria. MARTINI, 1958, pl. 5, fig. 24; Eocene, Germany. MANIVIT, 1959, pl. 10, figs. 1-5; Eocene, Africa, France. BALDI-BEKE, 1960, pl. 14, fig. 16; Oligocene-Miocene. MARTINI, 1960, pl. 8, fig. 10; Oligocene, Germany. BRAMLETTE and SULLIVAN, 1961, pl. 11, fig. 2; Eocene, California. STRADNER and PAPP, 1961, pl. 2, fig. 1; pl. 3, figs. 7, 17; Miocene, Czechoslovakia. BOUCHÉ, 1962, pl. 3, figs. 1-4; Eocene, France. Not HAY and TOWE, 1962, pl. 10, figs. 3, 5. STRADNER, 1962a, pl. 2, figs. 6-7; Eocene, Yugoslavia. BYSTRICKÁ, 1963, pl. 2, figs. 1-4; Eocene, Czechoslovakia. SULLIVAN, 1964, pl. 10, figs. 1-2; Paleocene, California. LEVIN, 1965, pl. 43, fig. 1; Eocene, Mississippi. LOCKER, 1965, pl. 1, fig. 1; Eocene, Germany. GARTNER and SMITH, 1967, pl. 12, figs. 1-3; Eocene, Louisiana. HAY, *et al.,* 1967, pl. 1, figs. 9-11; Eocene, Barbados. LEVIN and JOERGER, 1967, pl. 3, fig. 17; Eocene, Alabama. RADOMSKI, 1968, pl. 47, fig. 11; Eocene, Poland. BILGÜTAY, *et al.,* 1969, pl. 3, fig. 4; Eocene, France. BYSTRICKÁ, 1969, pl. 59, figs. 2-4; Eocene, Czechoslovakia. HODSON and WEST, 1970, pl. 1, fig. 5; Eocene, England. IACCARINO and FOLLINI, 1970, pl. 43, figs. 4-8; Paleocene, Italy. BALDI-BEKE, 1971, pl. 6, figs. 5-6; Eocene, Hungary. BUKRY, 1971, pl. 5, fig. 2; Eocene, Pacific. CLOCCHIATTI, 1971, pl. 30, figs. 1-4; Miocene-Pliocene, Africa. HAQ, 1971a, pl. 8, figs. 6-7; pl. 10, figs. 11-12; Paleocene, Persia. PERCH-NIELSEN, 1971b, pl. 51, fig. 5; Eocene, Denmark. LOCKER, 1972, pl.

14, figs. 1-2; pl. 17, fig. 3; Eocene, Europe. BUKRY, 1973, pl. 4, figs. 4-5; Eocene, Pacific. SHERWOOD, 1974, pl. 9, fig. 12; pl. 10, fig. 1; Eocene, Texas.

Heliodiscoaster barbadiensis (Tan Sin Hok). DEFLANDRE, 1934, text-figs. 22-23, 29-31. DEFLANDRE *in* GRASSÉ, 1952, text-fig. 362-V,V'; Miocene.

Actiniscus ilvensis PARÉJAS, 1934, text-fig. 29; Cretaceous, Elba.

Actiniscus decapetalus PARÉJAS, 1934, text-figs. 30-31; Cretaceous, Elba.

Actiniscus vernandi PARÉJAS, 1934, text-fig. 32; Cretaceous, Elba.

Remarks: D. barbadiensis is a robust asterolith with nine to fourteen rays which are connected for most of their length. Specimens are basket-shaped with a slender stem in the center. Ray terminations can be either rounded or pointed. The species lacks the concentric banding of *Discoaster elegans* Bramlette and Sullivan.

Occurrence: D. barbadiensis occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

DISCOASTER ELEGANS
Bramlette and Sullivan 1961

Plate 17, Figures 1-2

Discoaster elegans BRAMLETTE and SULLIVAN, 1961, pl. 11, fig. 16; Eocene, California. STRADNER and PAPP, 1961, pl. 28, fig. 16; text-fig. 9/8; Eocene, Mexico. BOUCHÉ, 1962, pl. 3, figs. 5-7; text-figs. 18-20; Eocene, France. BYSTRICKÁ, 1963, pl. 3, figs. 2-6. SULLIVAN, 1964, pl. 10, figs. 5-6; Paleocene, California. BUKRY and KENNEDY, 1969, figs. 3-7; Eocene, California. BYSTRICKÁ, 1969, pl. 59, figs. 7-10; Eocene, Czechoslovakia. BALDI-BEKE, 1971, pl. 6, fig. 9; Eocene, Hungary. LOCKER, 1972 pl. 14, figs. 12-14; pl. 15, fig. 1; Eocene, Europe. PERCH-NIELSEN, 1971b, pl. 51, figs. 2-3; Eocene, Denmark. SHERWOOD, 1974, pl. 10, figs. 2, 4; pl. 11, figs. 1-2; Eocene, Texas.

Discoaster barbadiensis Tan Sin Hok. HAY and TOWE, 1962, pl. 10, figs. 3, 5; Eocene, France.

Remarks: This robust, basket-shaped asterolith has 11 to 15 rays, which are joined for most of their length. There is a tall, slender knob in the center of the asterolith and several bands of concentric depressions parallel to the periphery. Each ray forms a fairly sharp peak at the periphery. *D. elegans* is similar to *Discoaster barbadiensis* Tan Sin Hok, but *D. barbadiensis* lacks the concentric depressions and has more rounded ray terminations.

Occurrence: D. elegans occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

DISCOASTER NODIFER
(Bramlette and Riedel) 1954

Plate 17, Figure 4

Discoaster tani nodifer BRAMLETTE and RIEDEL, 1954, pl. 39, fig. 2; Eocene, Alabama. MANIVIT, 1959, pl. 9, figs. 1-3; Eocene, France. MARTINI, 1960, pl. 9, fig. 19; Oligocene, Germany. NOEL, 1960, pl. 2, fig. 13; Eocene. LEVIN, 1965, pl. 43, figs. 5; Eocene, Mississippi. HAY, *et al.*, 1967, pl. 1, fig. 2; Eocene, Barbados. LEVIN and JOERGER, 1967, pl. 4, figs. 4-6; Oligocene, Alabama. Not HAQ, 1968, pl. 10, fig. 7. BYSTRICKÁ, 1969, pl. 62, fig. 2; Eocene, Czechoslovakia. ROTH, 1970, pl. 12, fig. 4; Oligocene. BALDI-BEKE, 1971, pl. 6, figs. 1-2; Eocene, Hungary. Not CLOCCHIATTI, 1971, pl. 38, fig. 2; Miocene, Africa. HAQ, 1971a, pl. 10, fig. 13; Eocene, Pakistan. HAQ, 1971b, pl. 12, fig. 4; Eocene-Oligocene, Germany. LOCKER, 1972, pl. 14, fig. 3; Eocene, Europe. SHERWOOD, 1974, pl. 11, fig. 5; Eocene, Texas.

Discoaster tani Bramlette and Riedel. DEFLANDRE and FERT, 1954, in part; pl. 11, figs. 13-15; Eocene, New Zealand.

Discoaster tani cf. *D. nodifer* Bramlette and Riedel. MARTINI, 1958, pl. 3, fig. 14; Eocene, Germany.

Discoaster binodosus hirundinus Martini. HAY, MOHLER, and WADE, 1966, pl. 13, fig. 2; Eocene, USSR.

Discoaster binodosus Martini. POZARYSKA and LOCKER, 1971, in part; pl. 3, fig. 32; Eocene, Poland. PERCH-NIELSEN, 1972, pl. 13, figs. 1-2; Eocene, Atlantic.

Discoaster nodifer (Bramlette and Riedel). BUKRY, 1973, pl. 4, fig. 23; Eocene-Oligocene, Pacific.

Remarks: D. nodifer normally has six rays, but may have five or seven. Each ray has a terminal medial notch and two nodes, one on each side of a ray and halfway down the unjoined portion. *Discoaster binodosus* Martini lacks the terminal notch. Little Stave Creek specimens have thicker rays than most illustrated specimens.

Occurrence: D. nodifer occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

DISCOASTER SAIPANENSIS
Bramlette and Riedel 1954
Plate 17, Figure 5

Discoaster saipanensis BRAMLETTE and RIEDEL, 1954, pl. 39, fig. 4; Eocene, Saipan. MARTINI, 1958, pl. 6, fig. 29; Eocene, Germany. MANIVIT, 1959, pl. 6, figs. 1-3; Eocene, France. STRADNER, 1959a, text-fig. 3; Eocene, Austria. BÁLDI-BEKE, 1960, pl. 14, fig. 20; Oligocene. MARTINI, 1960, pl. 8, fig. 12; Oligocene, Germany. NOËL, 1960, pl. 1, fig. 13; Eocene. STRADNER and PAPP, 1961, pl. 22, figs. 5-7; Eocene, Austria. STRADNER, 1962a, pl. 2, figs. 4-5; Eocene, Yugoslavia. LEVIN, 1965, pl. 43, fig. 2; Eocene, Mississippi. LOCKER, 1965, pl. 1, figs. 8-9; Eocene, Germany. HAY, MOHLER, and WADE, 1966, pl. 13, fig. 1; Eocene, USSR. GARTNER and SMITH, 1967, pl. 12, figs. 4-5; Eocene, Louisiana. HAQ, 1967, pl. 8, figs. 4, 6-7; Eocene, Pakistan. LEVIN and JOERGER, 1967, pl. 3, fig. 16; Eocene, Alabama. LOCKER, 1968, pl. 1, fig. 17; Eocene, Germany. RADOMSKI, 1968, pl. 48, fig. 2; Eocene, Poland. BILGÜTAY, *et al.*, 1969, pl. 3, fig. 5; Eocene, France. BYSTRICKÁ, 1969, pl. 59, figs. 11-13; Eocene, Czechoslovakia. BÁLDI-BEKE, 1971, pl. 6, figs. 3-4; Eocene, Hungary. CLOCCHIATTI, 1971, pl. 31, figs. 1-3; pl. 32, fig. 3; text-fig. 18; Miocene, Africa. MARTINI, 1971a, pl. 2, fig. 16; Eocene. PERCH-NIELSEN, 1971b, pl. 51, fig. 4; pl. 52, fig. 4; Eocene, Denmark. POZARYSKA and LOCKER, 1971, pl. 2, fig. 33; Eocene, Poland. BRATU and GHETA, 1972, pl. 2, figs. 27; Paleocene-Eocene, Czechoslovakia. LOCKER, 1972, pl. 15, fig. 10; Eocene, Europe. BUKRY, 1973, pl. 4, fig. 28; Eocene, Pacific. SHERWOOD, 1974, pl. 9, fig. 16; pl. 12, fig. 4; Eocene, Texas.

Discoaster cf. *D. saipanensis* Bramlette and Riedel. BENEŠOVÁ and HANZLÍKOVÁ, 1962, pl. 3, fig. 9; Miocene, Czechoslovakia.

Remarks: D. saipanensis normally has seven straight rays which are joined for one-half their length and then taper to a point. A small stem rises from the center of this species and irregularly-shaped depressions cover the surface. This species has fewer, more pointed rays than *Discoaster barbadiensis* Tan Sin Hok and *Discoaster elegans* Bramlette and Sullivan.

Occurrence: D. saipanensis occurs in the middle Eocene (Blow's P11-P14) of Alabama.

DISCOASTER sp. A

Plate 17, Figures 6-7

Remarks: This asterolith has six fairly long rays which widen near the periphery and then bifurcate. There is a small knob or stem in the central area. *Discoaster distinctus* Martini also is six-rayed with terminal bifurcations, but it has two knobs on each ray just behind the bifurcation.

Occurrence: Discoaster sp. A occurs only in the upper middle Eocene (Blow's P14) of Alabama.

Family GONIOLITHACEAE Deflandre 1957
Genus GONIOLITHUS Deflandre 1957
Type species: *Goniolithus fluckigeri* Deflandre

GONIOLITHUS FLUCKIGERI
Deflandre 1957
Plate 15, Figure 8

Goniolithus fluckigeri DEFLANDRE, 1957, text-figs. 1-4; Eocene, Germany. DEFLANDRE, 1962, text-figs. G-I. MARTINI, 1964, pl. 6, figs. 1-9; Maastrichtian-Oligocene. BLACK, 1968, pl. 151, fig. 6; Maastrichtian, Alabama. STRADNER and EDWARDS, 1968, pl. 41, text-figs. 8/1, 8/2; Eocene, New Zealand. MARTINI, 1969b, pl. 3, figs. 34-35; Oligocene, Switzerland. PERCH-NIELSEN, 1969, pl. 6, figs. 7-8; Danian-Oligocene, Europe. PERCH-NIELSEN, 1971b, pl. 46, fig. 7; Eocene, Den-

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PLATE 1

Figures Page

1-2. *Blackites* sp. aff. *B. creber* (Deflandre) Sample B-30 224
1. Electron micrograph, X17,400 Distal view
2a. Electron micrograph, X16,500 46° Tilt
2b. Electron micrograph, X17,400

3-4. *Blackites creber* (Deflandre) Sample B-30 224
3. Electron micrograph, X8,700
4. Electron micrograph X8,400

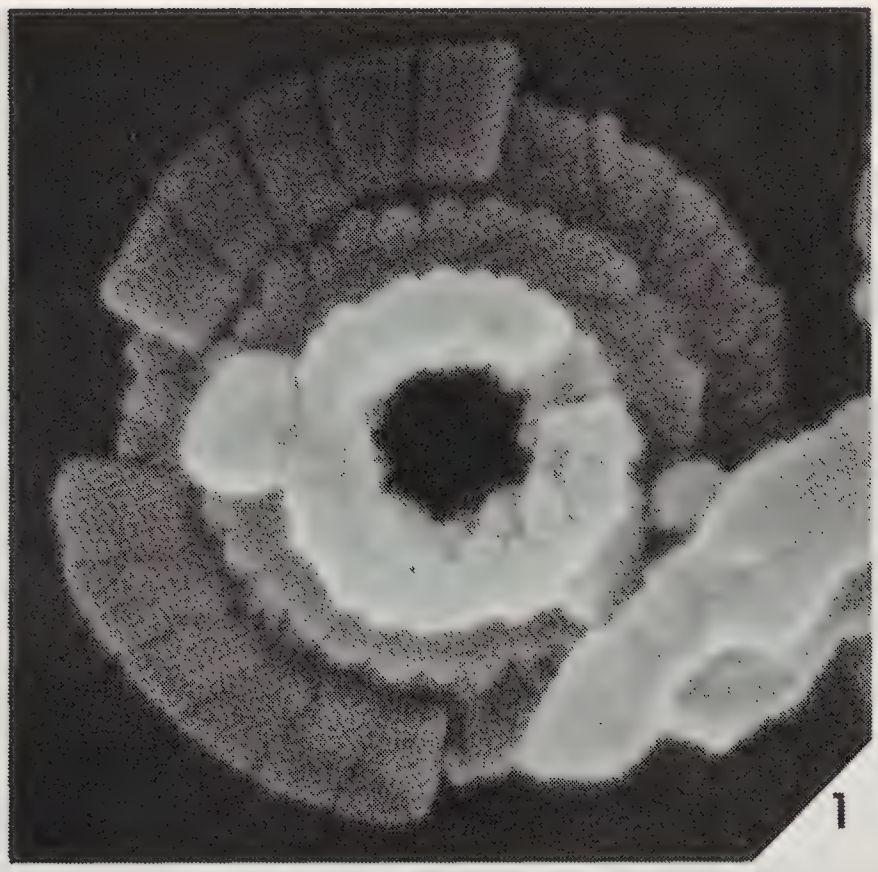
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PLATE 1

mark. LOCKER, 1972, pl. 11, figs. 7-9; Maastrichtian-Oligocene.

Goniolithus cf. *G. fluckigeri* Deflandre. HAY and MOHLER, 1967, pl. 202, figs. 4-5; Paleocene, France.

Braarudosphaera sp. HAQ, 1968, pl. 11, figs. 5-6; Eocene, Germany.

Remarks: The broad rim and unusual construction of the central area of *G. fluckigeri* distinguish it from other pentagonal species.

Occurrence: G. fluckigeri occurs in the upper middle Eocene (Blow's P14) of Alabama.

Family LITHOSTROMATIONACEAE
Deflandre 1959

Genus LITHOSTROMATION
Deflandre 1942

Type species: *Lithostromation perdurum* Deflandre

Remarks: Deflandre (1942) gave a single description for this genus and the type species *Lithostromation perdurum* Deflandre. The species *Trochoaster operosus* (Deflandre), *Marthasterites reginus* Stradner and *Trochoaster simplex* Klumpp are placed in this genus because all four species have numerous circular depressions with a surrounding hexagonal ridge, no discernible crystals, and three-way symmetry (or a multiple).

LITHOSTROMATION OPEROSUM
(Deflandre) 1954 n. comb.

Plate 19, Figures 1, 3-4

Polycladolithus operosus DEFLANDRE *in* DEFLANDRE and FERT, 1954, pl. 12, figs. 3-6; text-fig. 125; Oligocene, New Zealand; Eocene, France. STRADNER, 1959b, text-fig. 73; Eocene, Austria. BRAMLETTE and SULLIVAN, 1961, pl. 14, fig. 13; Eocene, California. SULLIVAN, 1964, pl. 9, fig. 8; Paleocene, California.

Trochoaster operosus (Deflandre). STRADNER and PAPP, 1961, pl. 41, fig. 6; Eocene, Austria. BOUCHÉ, 1962, pl. 4, figs. 7-8; Eocene, France. BILGÜTAY, *et al.,* 1969, pl. 5, figs. 5-7; Eocene, France. HODSON and WEST, 1970, pl. 4, fig. 8; Eocene, England. BALDI-BEKE, 1971, pl. 6, figs. 10, 17; Eocene, Hungary. LOCKER, 1972, pl. 16, fig. 15; Eocene, Europe.

Remarks: This species has a spherical body with an irregular, knobby surface and numerous circular depressions. Each depression is surrounded by a hexagonal ridge with a knob at each corner of the hexagon. Some specimens have six large projections evenly spaced around the equator of the sphere. There are no discernible crystal elements and *L. operosum* is dark under cross-polarized light.

Occurrence: L. operosum occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

LITHOSTROMATION PERDURUM
Deflandre 1942
Plate 19, Figure 6

Lithostromation perdurum DEFLANDRE, 1942, text-figs. 1-9. DEFLANDRE *in* GRASSÉ, 1952, figs. 364-F-H; Eocene, France. STRADNER, 1959b, figs. 70-72; Eocene, Austria. BACHMANN, PAPP, and STRADNER, 1963, pl. 24, fig. 12; Austria. MARTINI and BRAMLETTE, 1963, pl. 102, fig. 8; Pliocene, Italy. LEVIN and JOERGER, 1967, pl. 3, figs. 12-13; pl. 4, fig. 14; Eocene-Oligocene, Alabama. MARTINI, 1969a, pl. 28, fig. 9; Miocene, Africa. HODSON and WEST, 1970, pl. 3, fig. 5; Eocene, England. ROTH, 1970, pl. 13, figs. 1-2; Oligocene, Alabama, JOIDES 5. BALDI-BEKE, 1971, pl. 6, fig. 18; Eocene, Hungary. CLOCCHIATTI, 1971, pl. 21, figs. 1-2; Miocene-Pliocene, Africa. LEHOTAYOVÁ, 1971, pl. 5, fig. 2; Miocene, Yugoslavia. PERCH-NIELSEN,

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PLATE 2

Figures Page

1-5. *Blackites spinosus* (Deflandre) Sample B-30 226
1. Electron micrograph, X8,700 Distal view
2. Electron micrograph, X8,700 Proximal view
3a. Cross-polarized light, X2,200
3b. Phase contrast, X2,200
4. Electron micrograph, X5,200
5. Electron micrograph, X15,900

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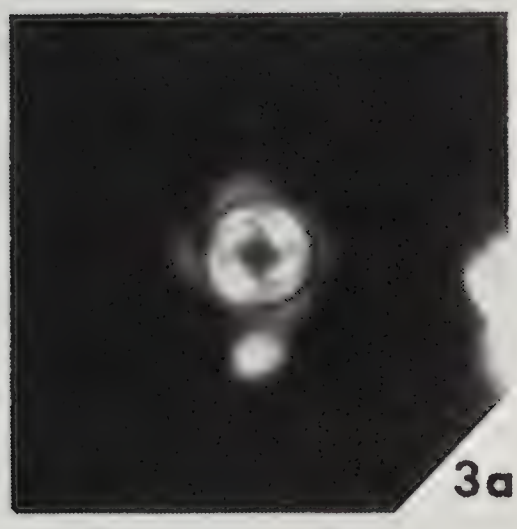
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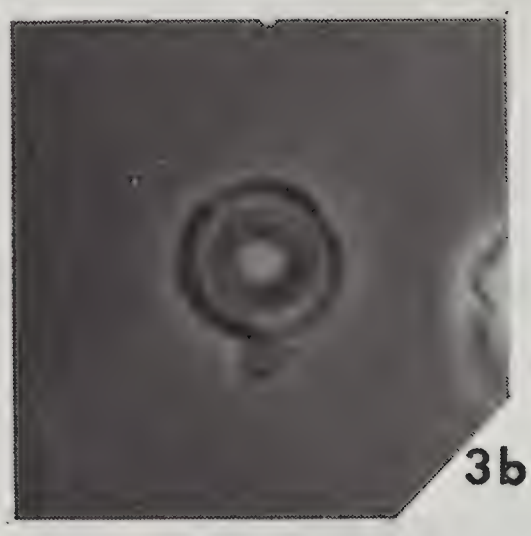
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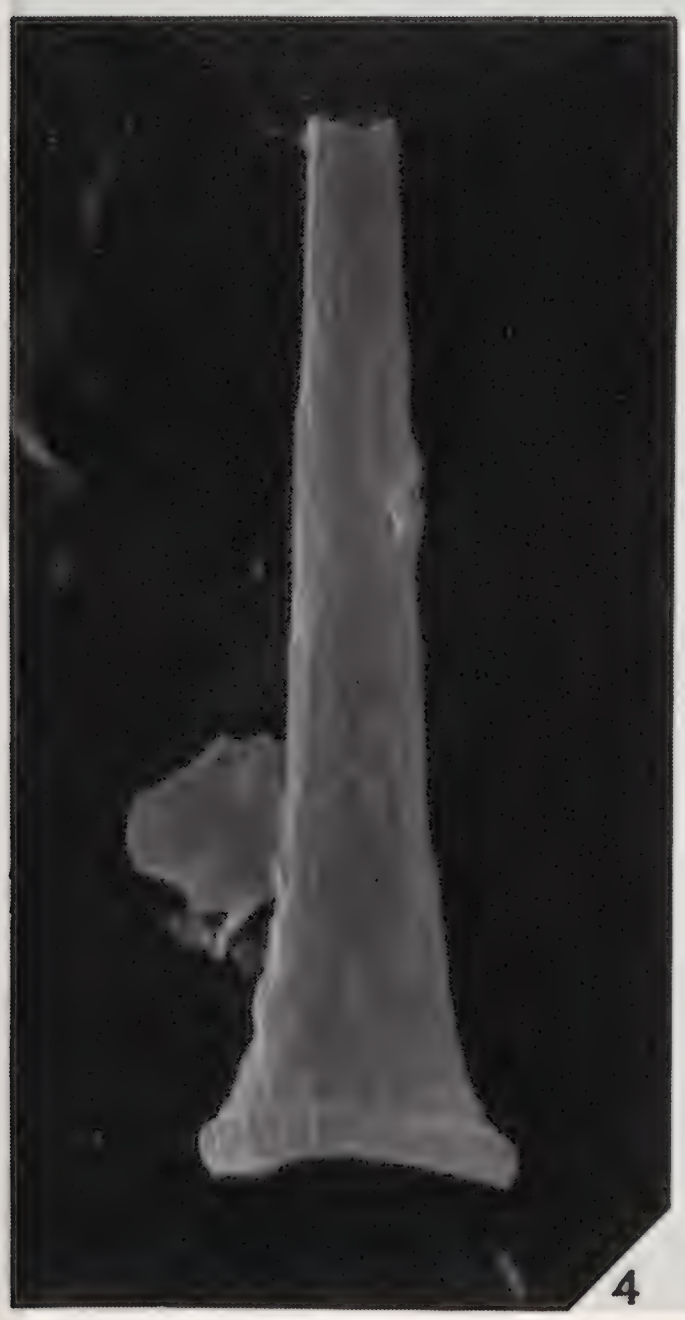
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PLATE 2

1971b, pl. 57, fig. 6; Eocene, Denmark. POZARYSKA and LOCKER, 1971, pl. 16, figs. 12-14; Eocene, Europe.
Lithostromation reticulum GARDET, 1955, pl. 11, fig. 1-3; Miocene, Algeria.
Lithostromation triangularis GARDET, 1955, pl. 11, fig. 1-2; Miocene, Algeria. LEHOTAYOVÁ, 1970, pl. 30, figs. 1, 3; Miocene, Yugoslavia.
Trochoaster triangularis (Gardet). BÁLDI-BEKE, 1960, pl. 14, fig. 21; Miocene, Hungary.
Lithostromation robustum MARTINI, 1961b, fig. 1; Oligocene, Germany. MARTINI, 1971a, pl. 1, fig. 3; Oligocene, Germany.
Lithostromation sp. HAQ, 1967, pl. 6, fig. 6; Eocene, Pakistan.

Remarks: L. perdurum has a triangular body which thickens toward its center. The irregular, knobby surface is covered with numerous, circular depressions. Each depression is surrounded by a hexagonal, knobby ridge. There are no discernible crystal elements. The structure of the species is similar to *Lithostromation simplex* (Klumpp) and *Lithostromation operosum* (Deflandre), but has a triangular outline, while the others have hexagonal and circular outlines respectively.

Occurrence: L. perdurum occurs in the upper middle Eocene (Blow's P14) of Alabama.

LITHOSTROMATION REGINUM (Stradner) 1962b n. comb.

Plate 19, Figure 5

Marthasterites reginus STRADNER, 1962b, pl. 3, figs. 6-10; Eocene.

Remarks: This species has six long, slender rays arranged in the same pattern as the playing pieces for the children's game of jacks. There are six knobs at the termination of each ray. The surface is covered with circular depressions which are surrounded by hexagonal, knobby ridges. The perforations become more shallow and more oval toward the ray ends. *L. reginum* is similar to *Marthasterites spineus* Shafik and Stradner, which is distinguished by its lack of terminal nodes and the presence of small projections on either side of each ray.

Occurrence: L. reginum was observed only in the upper middle Eocene (Blow's P14) of Alabama.

LITHOSTROMATION SIMPLEX (Klumpp) 1953 n. comb.

Plate 19, Figure 2

Trochoaster simplex KLUMPP, 1953, pl. 16, fig. 7; text-fig. 4 (2); Eocene, Germany. MARTINI, 1958, pl. 5, fig. 25; Eocene, Germany. MARTINI, 1960, pl. 10, fig. 35; Oligocene, Germany. MARTINI and STRADNER, 1960, fig. 19. STRADNER and PAPP, 1961, pl. 42, figs. 1-4, 6; Eocene, Austria. BOUCHÉ, 1962, pl. 4, fig. 6; Eocene, France. LEVIN, 1965, pl. 43, figs. 7-9; Eocene, Mississippi. LOCKER, 1965, pl. 2, fig. 2; Eocene, Germany. LEVIN and JOERGER, 1967, pl. 3, figs. 20-21; Eocene-Oligocene, Alabama. HAQ, 1968, pl. 11, figs. 7-8; Eocene, Germany. BYSTRICKÁ, 1969, pl. 64, fig. 10; Paleogene, Czechoslovakia. MARTINI, 1971b, pl. 1, fig. 2; Eocene, Germany. PERCH-NIELSEN, 1971b, pl. 57, fig. 8; Eocene, Denmark. LOCKER, 1972, pl. 16, figs. 17-18; Eocene, Europe. SHERWOOD and LEVIN, 1972, text-fig. 1. SHERWOOD, 1974, pl. 8, figs. 9-10; pl. 9, fig. 8; Eocene, Texas.
Trochoaster duplex KLUMPP, 1953, pl. 16, fig. 10; text-fig. 4 (3); Eocene, Germany.
Discoaster bramlettei MARTINI, 1958, pl. 3, fig. 11; Eocene, Germany.

Remarks: This species has a hexagonal outline which thickens towards its center. The surface is pitted with circular perforations which are surrounded by knobby, hexagonal ridges. Each apex of the hexagon ends in a short ray. The planar hexagonal shape distinguishes *L. simplex* from other species in this genus.

PLATE 3

Figures Page

1-4. *Blackites spinosus* (Deflandre) Sample B-30 226
1. Electron micrograph, X8,700
2. Electron micrograph, X8,700
3. Electron micrograph, X1,700
4a. Cross-polarized light, X2,200
4b. Phase contrast, X2,200

1

2

3

4a

4b

PLATE 3

Occurrence: L. simplex occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

Family PONTOSPHAERACEAE
Lemmermann 1908

Genus DISCOLITHINA
Loeblich and Tappan 1963
Type species: *Discolithus vigintiforatus*
Kamptner

DISCOLITHINA BICAVEATA
Perch-Nielsen 1967

Plate 21, Figure 6

Discolithina bicaveata PERCH-NIELSEN, 1967, pl. 4, figs. 8-10; Eocene, Denmark. PERCH-NIELSEN, 1971b, pl. 27, fig. 7; Eocene, Denmark.

Remarks: This basket-shaped discolith has a fairly high, slanting rim and two small, irregularly-shaped holes in the central area. A fissure connects the two holes and also extends outward beyond each hole. Little Stave Creek specimens have the holes slightly farther apart than those figured by Perch-Nielsen. The base is composed of rods of calcite that radiate from the center toward the periphery; these rods then spiral outward and upward to form the sides of the discolith. *D. bicaveata* differs from *Discolithina ocellata* (Bramlette and Sullivan) in having a basket shape and the structure of the base consists of radiating rods rather than the narrow layers of crystals parallel to the margin found in *D. ocellata.*

Occurrence: D. bicaveata occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

DISCOLITHINA CRIBRARIA
Perch-Nielsen 1967

Plate 20, Figure 3

Discolithina cribraria PERCH-NIELSEN, 1967, pl. 2, figs. 1-3; Eocene, Denmark.
Pontosphaera rothi HAQ, 1971b, pl. 4, figs. 1-2; pl. 5, figs. 6-7; Oligocene, Germany.
Pontosphaera cribraria (Perch-Nielsen). HAQ, 1971c, pl. 11, figs. 1-4; Oligocene, Syria.

Remarks: This discolith has circular pores in the central portion of the base and around the margin are larger, circular to rectangular perforations. The structure is similar to *Discolithina multipora* (Kamptner), although that species has smaller, more uniformly-sized pores. The bases of discoliths of this type have the narrow layers of crystals parallel to the periphery in the distal view and radiating laths on the concave proximal side. Because of nearly vertical sides, *D. cribraria* appears to have little or no rim under the light microscope.

Occurrence: D. cribraria occurs in the middle Eocene (Blow's P11-P14) of Alabama.

DISCOLITHINA MULTIPORA
(Kamptner) 1948
Plate 20, Figures 1, 4

Discolithus multiporus KAMPTNER, 1948, pl. 1, fig. 9; Miocene, Austria. STRADNER, 1962, text-figs. 4-8; Oligocene, Austria. STRADNER and ADAMIKER, 1966, pl. 3, fig. 1; Eocene, Austria. CLOCCHIATTI, 1971, in part; text-fig. 6; pl. 12, figs. 1-6; Miocene-Pliocene, Africa.
Discolithus vigintiforatus KAMPTNER, 1948, pl. 1, fig. 8; Miocene, Austria.
Discolithus lineatus DEFLANDRE *in* DEFLANDRE and FERT, 1954, pl. 10, figs. 17-18; text-fig. 50; Miocene-Pliocene, France.
Discolithus sp. B BALDI-BEKE, 1960, pl. 14, fig. 3; Oligocene-Miocene, Hungary.

PLATE 4

Figures Page

1-5. *Blackites tenuis* (Bramlette and Sullivan) Sample B-30 228
1. Electron micrograph, X1,700
2a. Cross-polarized light, X2,200
2b. Phase contrast, X2,200
3. Electron micrograph, X17,400
4. Electron micrograph, X17,400
5a. Electron micrograph, X4,300
5b. Electron micrograph, X8,700

1

2a

2b

5a

3

4

5b

PLATE 4

Discolithus distinctus BRAMLETTE and SULLIVAN, 1961, in part; pl. 2, fig. 9; Eocene, California, Texas, Trinidad, France. SULLIVAN, 1964, pl. 4, fig. 4; Paleocene, California. SULLIVAN, 1965, pl. 4, figs. 1-6; Eocene, California. REINHARDT, 1967, pl. 3, fig. 4; Eocene, Germany. LOCKER, 1972, pl. 1, figs. 4-5; Oligocene, Europe.

Cribrosphaerella sp. BENEŠOVÁ and HANZLÍKOVÁ, 1962, pl. 2, fig. 9; Eocene, Czechoslovakia.

Discolithina confossa HAY, MOHLER, and WADE, 1966, in part; pl. 9, fig. 1; Eocene, USSR. HAY, *et al.*, 1967, pl. 7, figs. 7-8. LOCKER, 1968, pl. 1, fig. 18; Eocene, Germany.

Discolithina vigintiforata (Kamptner). BRAMLETTE and WILCOXON, 1967, pl. 5, figs. 3-4; Oligocene-Miocene, Trinidad.

Discolithina aff. *D. distincta* (Bramlette and Sullivan). GARTNER and SMITH, 1967, pl. 6, figs. 4-6; Eocene, Louisiana.

Discolithina distincta (Bramlette and Sullivan). LEVIN and JOERGER, 1967, pl. 1, figs. 14-15; Eocene-Oligocene, Alabama. MARTINI, 1969b, pl. 1, figs. 7-8; Eocene-Oligocene, Germany. POZARYSKA and LOCKER, 1971, pl. 3, fig. 2; Eocene, Poland.

Discolithina enormis LOCKER, 1967, pl. 2, figs. 5-6; pl. 1, fig. 4; Miocene-Oligocene, Germany. LOCKER, 1968, pl. 1, fig. 19; Oligocene-Miocene, Germany.

Pontosphaera vadosa Hay, Mohler, and Wade. PERCH-NIELSEN, 1967, in part; pl. 2, figs. 7-8; Eocene, Denmark.

Discolithus distinctoides REINHARDT, 1967, pl. 3, figs. 2-3; text-fig. 13; Eocene, Germany.

Discolithina multipora (Kamptner). HAQ, 1968, pl. 6, figs. 4-9; Eocene, Germany. STRADNER and EDWARDS, 1968, in part; pl. 32; pl. 34; pl. 35, figs. 1-4; Eocene, New Zealand. MARTINI, 1969a, pl. 26, figs. 5-6; Miocene, Africa. LEHOTAYOVÁ, 1970, pl. 24, figs. 1-3; Miocene, Yugoslavia. BALDI-BEKE, 1971, pl. 1, figs. 2-4; Eocene, Hungary. LEHOTAYOVA, 1971, pl. 1, fig. 2; Miocene, Yugoslavia. PERCH-NIELSEN, 1971b, pl. 26, figs. 1-5; Eocene, Denmark.

Discolithus confossa (Hay, Mohler, and Wade). HODSON and WEST, 1970, pl. 2, fig. 7; Eocene, England.

Pontosphaera multipora (Kamptner). HANZLÍKOVÁ, 1971, pl. 2, fig. 1; Oligocene, Czechoslovakia. HAQ, 1971b, pl. 4, figs. 4-6, 8-9; pl. 7, figs. 3-4; pl. 14, figs. 4-5; Eocene-Oligocene, Germany. Not ELLIS, LOHMAN, and WRAY, 1972, pl. 6, figs. 4-7; pl. 7, figs. 1-2. SHERWOOD, 1974, in part; pl. 3, figs 15-16; pl. 4, fig. 9; Eocene, Texas.

Remarks: This species has circular pores of uniform size on its surface, which are arranged in rows parallel to the periphery. The proximal side is concave and composed of outward radiating rods of calcite and the distal side is larger with bands of crystals parallel to the periphery. Ridges between the pores give the distal side an irregular, bumpy surface. *D. multipora* has larger holes than *Discolithina vesca* (Sullivan) and lacks the outer ring of large perforations present in *Discolithina cribraria* Perch-Nielsen.

Occurrence: *D. multipora* occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

DISCOLITHINA VESCA
(Sullivan) 1965 n. comb.

Plate 20, Figure 2

Discolithus vescus SULLIVAN, 1965, pl. 4, fig. 9; Paleocene-Eocene, California.

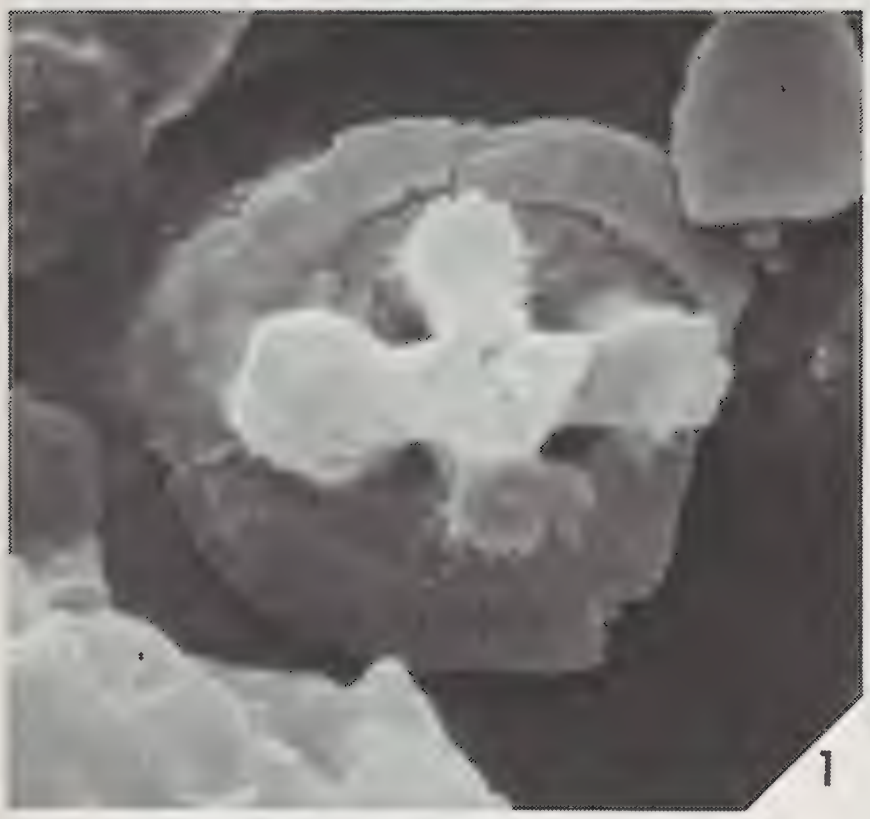
PLATE 5

Figures Page

1-3. *Rhabdosphaera vitrea* (Deflandre) Sample B-30 230
1. Electron micrograph, X8,700 Distal view
2. Electron micrograph, X8,400
3. Electron micrograph, X17,400

4. *Blackites* sp. A Sample B-30 230
4a. Cross-polarized light, X2,200
4b. Phase contrast, X2,200

5-6. *Cepekiella lumina* (Sullivan) Sample B-30 236
5a. Cross-polarized light, X2,200
5b. Phase contrast, X2,200
6a. Cross-polarized light, X2,200
6b. Phase contrast, X2,200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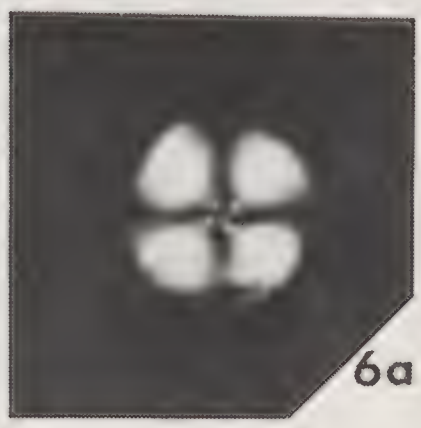
4a

4b

5a

5b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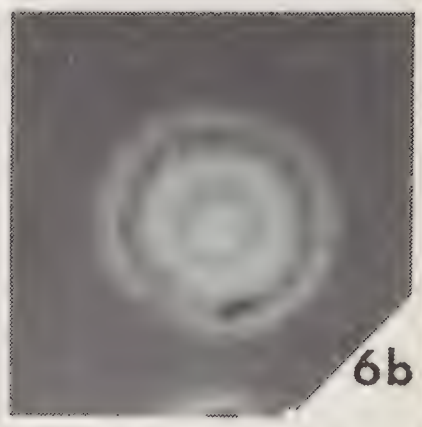
6b

PLATE 5

Remarks: D. vesca has numerous, small, circular pores on its surface, which are arranged in concentric rows. There may be a row of larger triangular pores along the outer margin and the rim is thin. This species closely resembles *Discolithina multipora* (Kamptner), differing from it mainly in possessing more numerous and smaller pores. The crystal structure is probably similar to that of *D. multipora,* but there are no electron photo micrographs of *D. vesca* to confirm this similarity.

Occurrence: D. vesca occurs in the middle Eocene (Blow's P11-P14) of Alabama.

DISCOLITHINA WECHESENSIS (Bukry and Percival) 1971 n. comb.

Plate 22, Figure 2

Syracosphaera? wechesensis BUKRY and PERCIVAL, 1971, pl. 7, figs. 7-10; Eocene, Texas, USSR.

Discolithina amphitheatralis LEVIN and SHERWOOD, 1971, text-fig. 1; Eocene, Texas.

Discolithina aperta PERCH-NIELSEN, 1971b, pl. 30, fig. 1; Eocene, Denmark.

Koczyia excelsa PERCH-NIELSEN, 1971b, pl. 28, figs. 1-5; pl. 60, fig. 16; Eocene, Denmark.

Koczyia wechesensis (Bukry and Percival). SHERWOOD, 1974, p. 4, figs. 5-6; pl. 5, figs. 5-6; Eocene, Texas.

Remarks: This lopadolith has one fairly large, elliptical to subcircular central opening and high walls. A series of regularly spaced vertical struts line the inside wall; between each strut is a circular depression in the base. This base is formed of thin bands of calcite, which are parallel to the periphery, and the sides are constructed of upward and outward spiraling laths. The sides flare out at the top of the specimen and form a wide rim.

Occurrence: D. wechesensis occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

DISCOLITHINA sp. A

Plate 20, Figure 5

Remarks: The base of this lopadolith is covered with very small pores. The walls are thick and a depression is incised into their flat, upper surface. This depression has the appearance of inner and outer wall bands, the inner portion higher than the other. Individual calcite crystals are not visible on Little Stave Creek specimens and it is not possible to ascertain to which discolith category this form belongs.

Occurrence: Discolithina sp. A was observed only in the upper middle Eocene (Blow's P14) of Alabama.

DISCOLITHINA sp. B

Plate 22, Figure 4

Discolithus fimbriatus Bramlette and Sullivan. SULLIVAN, 1965, pl. 5, fig. 1; Eocene, California.

Remarks: This lopadolith has high walls and a long narrow slit running lengthwise across its base. There appears to be a series of struts around the periphery of the base similar to those found on *Discolithina wechesensis* (Bukry and Percival), but only electron microscopy can confirm this. At the top of the lopadolith the wall flares out to form a broad rim. This species is similar to *Discolithina wechesensis,* which has one large opening in its base and to *Transversopontis fimbriatus* (Bramlette and Sullivan), which has two basal openings.

Occurrence: Discolithina sp. B occurs in the upper middle Eocene (Blow's P14) of Alabama.

Genus HELICOPONTOSPHAERA Hay and Mohler 1967

Type species: *Helicopontosphaera kamptneri* Hay and Mohler

PLATE 6

Figures Page

1-3. *Blackites trochos* n.sp. Sample B-30 230
1. Electron micrograph, X8,700 Distal view
2a. Electron micrograph, X9,600 59° Tilt
2b. Electron micrograph, X10,400 10° Tilt Distal view
3. Electron micrograph, X8,700

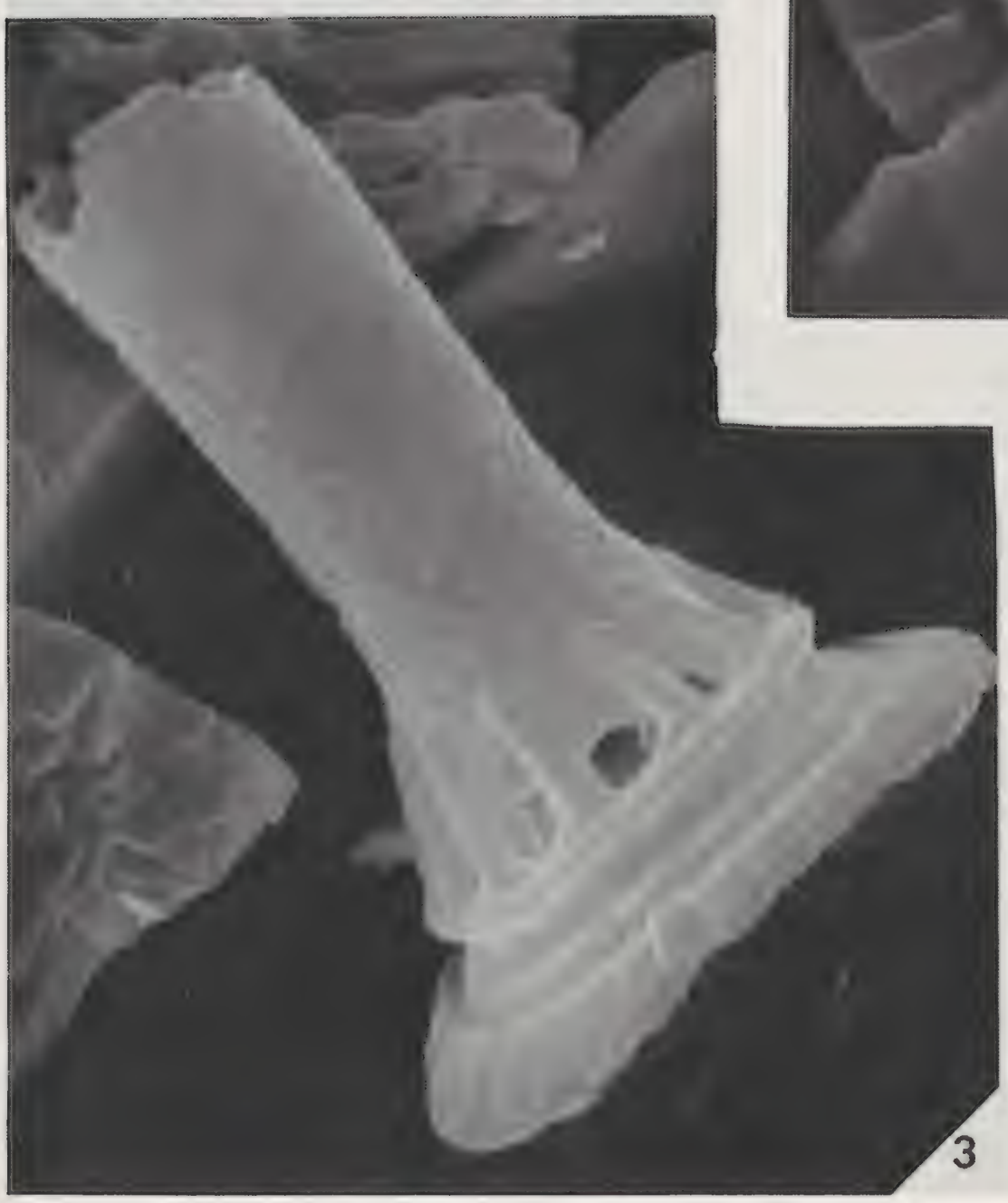

PLATE 6

HELICOPONTOSPHAERA COMPACTA (Bramlette and Wilcoxon) 1967 Plate 18, Figure 4

Helicosphaera compacta BRAMLETTE and WILCOXON, 1967, pl. 6, figs. 5-8; Oligocene, Trinidad. LOCKER, 1972, pl. 9, figs. 16-19; Eocene, Europe.

Helicopontosphaera compacta (Bramlette and Wilcoxon). ROTH, 1970, pl. 10, figs. 2, 4?; Eocene-Oligocene, Alabama, Trinidad, Italy, JOIDES 5-6. HAQ, 1971c, pl. 6, figs. 6-7; pl. 7, figs. 4-5; pl. 8, figs. 6-8; pl. 9, figs 1-3; Oligocene, Syria. Not PERCH-NIELSEN, 1971b, pl. 34, fig. 6. HAQ, 1973, pl. 2, fig. 6; pl. 7, figs. 1-2; Eocene-Oligocene.

Helicopontosphaera rhomboidalis (Locker). POZARYSKA and LOCKER, 1971, pl. 2, figs. 22-23; Eocene, Poland.

Remarks: H. compacta is ovoid in outline and the terminal flange of the distal shield merges into the previous whorl. The central area has two small oval openings with the long axes parallel to the longitudinal axis of the specimen. The small proximal shield is bright and distinct under the light microscope.

Occurrence: H. compacta occurs in the upper middle Eocene (Blow's P14) of Alabama.

HELICOPONTOSPHAERA LOPHOTA (Bramlette and Sullivan) 1961

Helicosphaera seminulum lophota BRAMLETTE and SULLIVAN, 1961, pl. 4, figs. 3-4; Eocene, California, Texas, France. SULLIVAN, 1964, pl. 5, fig. 2; Paleocene, California. SULLIVAN, 1965, pl. 6, fig. 5; Eocene, California. Not PERCH-NIELSEN, 1967, pl. 3, figs. 1-3. BUKRY and KENNEDY, 1969, figs. 4-2, 4-3; Eocene, California. BALDI-BEKE, 1971, pl. 3, fig. 9; Eocene, Hungary.

Helicosphaera seminulum Bramlette and Sullivan. GARTNER and SMITH, 1967, in part; pl. 7, figs. 1-4; Eocene, Louisiana.

Helicopontosphaera cf. *H. lophota* (Bramlette and Sullivan). HAQ, 1971a, pl. 3, fig. 2; Paleocene, Persia; Eocene, Pakistan.

Helicopontosphaera lophota (Bramlette and Sullivan). HAQ, 1971b, pl. 3, fig. 12; Oligocene, Germany. Not HAQ, 1971c, pl. 10, figs. 8-9. PERCH-NIELSEN, 1971b, in part; pl. 34, figs. 1-2; pl. 36, fig. 2; Eocene, Denmark. HAQ, 1973, pl. 1, figs. 1-3; pl. 3, figs. 3-4; Eocene.

PLATE 7

Figures Page

1-3. *Braarudosphaera bigelowi* (Gran and Braarud) Sample B-30 187
1. Electron micrograph, X5,200
2a. Cross-polarized light, X2,200
2b. Phase contrast, X2,200
3a. Transmitted light, X2,200 Plan view
3b. Transmitted light, X2,200 Side view

4. *Braarudosphaera irregularis* Bybell and Gartner Sample B-30 188
4a. Cross-polarized light, X2,200
4b. Phase contrast X2,200

5. *Braarudosphaera cheloma* Bybell and Gartner Sample B-30 188
5a. Cross-polarized light, X2,200
5b. Phase contrast, X2,200

6. *Braarudosphaera* sp. cf. *B. rosa* Levin and Joerger Sample B-30 188
6a. Cross-polarized light, X2,200
6b. Phase contrast, X2,200

7. *Micrantholithus ornatus* Sullivan Sample B-30 189
7a. Cross-polarized light, X2,200
7b. Phase contrast, X2,200

8. *Pemma* sp. A Sample B-30 192
8a. Cross-polarized light, X2,200
8b. Phase contrast, X2,200
8c. Dark field, X2,200

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2a

2b

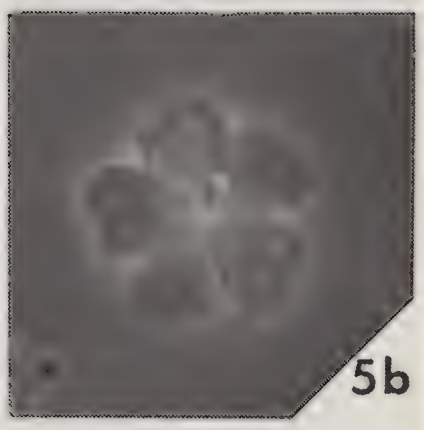
3a

3b

4a

4b

5a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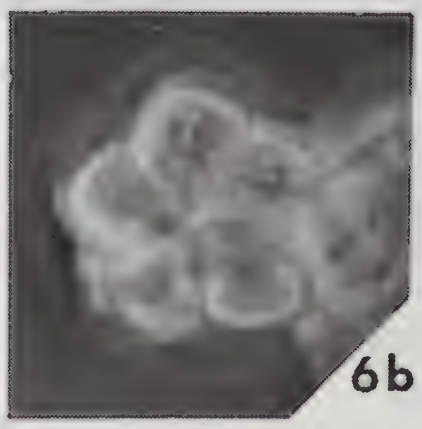
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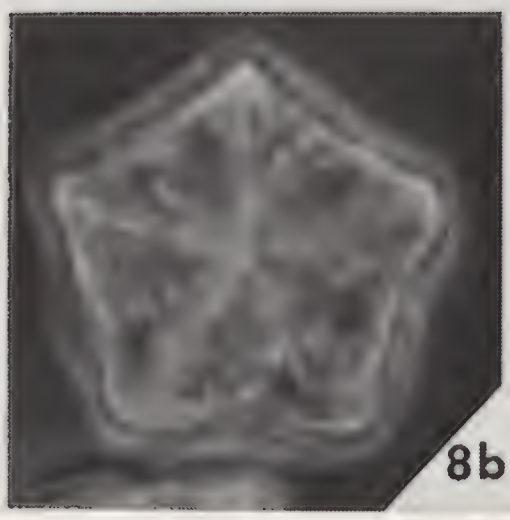
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PLATE 7

SHERWOOD, 1974, pl. 5, figs. 13-14; Eocene, Texas.

Helicopontosphaera seminulum (Bramlette and Sullivan). POZARYSKA and LOCKER, 1971, pl. 2, fig. 24; Eocene, Poland.

Helicosphaera lophota (Bramlette and Sullivan). LOCKER, 1972, pl. 9, figs. 14-15; Eocene, Europe.

Remarks: One end of the distal shield of *H. lophota* is much more rounded than the other. There is a broad, double bar across the central opening that is more closely aligned to the longitudinal than to the transverse axis. The outer whorl, which has segments discernible in the light microcsope, merges into the previous whorl and there is no flange. *H. lophota* is similar to *Helicopontosphaera wilcoxoni* Gartner, but the latter has a definite protruding flange. In *Helicopontosphaera seminulum* (Bramlette and Sullivan) the crossbar is oriented parallel to the transverse axis.

Occurrence: H. lophota occurs in the lower middle Eocene (Blow's P11) of Alabama.

HELICOPONTOSPHAERA RETICULATA (Bramlette and Wilcoxon) 1967

Plate 18, Figure 8

Helicosphaera reticulata BRAMLETTE and WILCOXON, 1967, pl. 6, fig. 15; Eocene-Oligocene, Mississippi; Oligocene, JOIDES. GARTNER, 1971, pl. 1; Eocene-Oligocene, Blake Plateau. HAQ, 1973, pl. 2, fig. 1; pl. 3, figs. 1-2; Eocene-Oligocene. MARTINI, 1971b, pl. 3, figs. 3-4; Eocene-Oligocene.

Helicopontosphaera reticulata (Bramlette and Wilcoxon). ROTH, 1970, pl. 10, fig. 5; Oligocene, Alabama, Barbados, Blake Plateau.

Helicopontosphaera salebrosa PERCH-NIELSEN, 1971b, pl. 34, fig. 5; pl. 36, figs. 5, 10; pl. 61, figs. 8-9; Eocene, Denmark.

Remarks: This species is subrhomboid in outline with an oblique central bridge, which is surrounded by two rows of small pores. There is little or no extension of the outer whorl into a flange. *H. reticulata* is similar to *Helicopontosphaera dinesenii* Perch-Nielsen, but the latter has a more ovoid outline and the central area has several rows of small pores, instead of the two rows found in *H. reticulata.*

Occurrence: H. reticulata occurs in the upper middle Eocene (Blow's P14) of Alabama.

HELICOPONTOSPHAERA SEMINULUM (Bramlette and Sullivan) 1961

Plate 18, Figure 5

Helicosphaera seminulum seminulum BRAMLETTE and SULLIVAN, 1961, pl. 4, figs. 1-2; Eocene, California, France. HAY and TOWE, 1962, pl. 1, figs. 1-3, 5; Eocene, France. SULLIVAN, 1964, pl. 5, fig. 1; Paleocene, California. PERCH-NIELSEN, 1967, pl. 3, figs. 4-5; Eocene, Denmark. Not CLOCCHIATTI, 1971, pl. 17, figs. 2-4; Miocene-Pliocene, Africa.

Helicosphaera seminulum Bramlette and Sullivan. GARTNER and SMITH, 1967, pl. 7, figs. 1-4; Eocene, Louisiana. Not STRADNER and EDWARDS, 1968, pls. 39-40. LOCKER, 1972, pl. 10, figs. 1-3.

PLATE 8

Figures Page

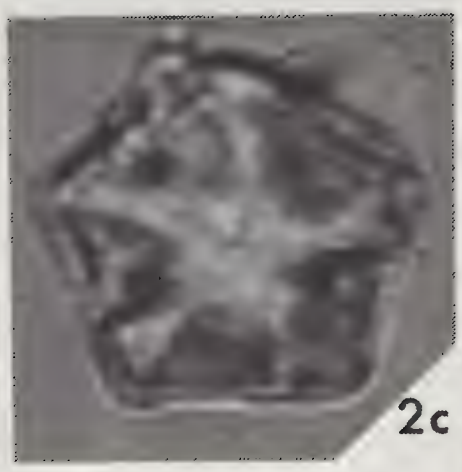
1-2. *Braarudosphaera stylifer* Troelson and Quadros Sample B-30 188
1. Electron micrograph, X4,400
2a. Phase contrast, X2,200 Side view
2b. Transmitted light, X2,200 Side view
2c. Transmitted light, X2,200 Plan view
2d. Transmitted light, X2,200 Plan view

3-5. *Pemma balium* Bybell and Gartner Sample B-30 190
3a. Cross-polarized light, X2,200
3b. Phase contrast, X2,200
4a. Cross-polarized light, X2,200
4b. Phase contrast, X2,200
5. Electron micrograph, X8,500

1

2a

2b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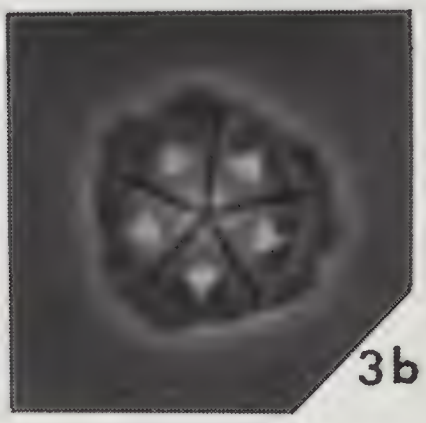
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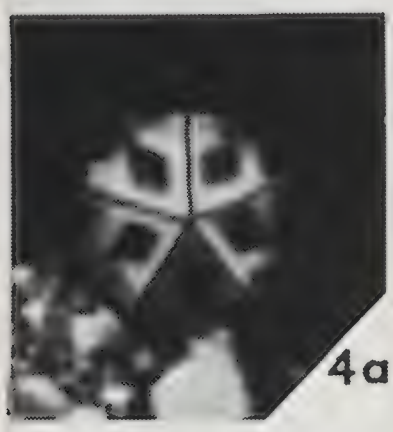
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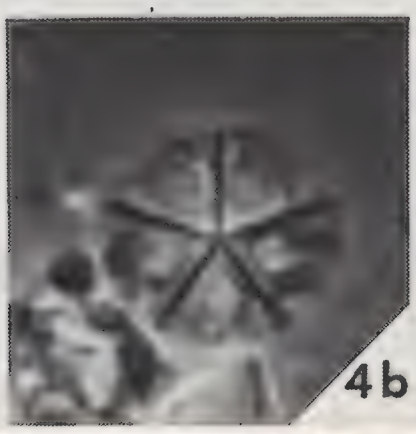
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PLATE 8

Helicosphaera sp. BUKRY and KENNEDY, 1969, fig. 4-1; Eocene, California.
Helicopontosphaera seminulum (Bramlette and Sullivan). PERCH-NIELSEN, 1971b, pl. 34, fig. 4; pl. 35, figs. 1-2, 5-6; pl. 37, fig. 6; Eocene, Denmark. Not POZARYSKA and LOCKER, 1971, pl. 2, fig. 24. PERCH-NIELSEN, 1972, pl. 18, figs. 7, 10; Eocene, Atlantic. HAQ, 1973, pl. 1, fig. 4; pl. 3, figs. 7-8; Eocene. SHERWOOD, 1974, pl. 5, figs. 9-10; pl. 6, fig. 8; Eocene, Texas.
Helicopontosphaera lophota (Bramlette and Sullivan). PERCH-NIELSEN, 1971b, in part; pl. 36, fig. 1; Eocene, Denmark.

Remarks: This broadly elliptical species has a large, elliptical central area spanned by a wide double bridge that is parallel to the transverse axis. There is no flange and the outer whorl merges into the previous whorl. The bridge is optically distinct from the rest of the specimen. Segments of the outer whorl are normally visible with phase contrast. *Helicopontosphaera lophota* (Bramlette and Sullivan) has the crossbar aligned with the short axis and *Helicopontosphaera wilcoxoni* Gartner has a less rounded outline, a distinct flange, and a slightly angled crossbar.

Occurrence: H. seminulum occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

HELICOPONTOSPHAERA WILCOXONI Gartner 1971

Plate 18, Figures 6-7

Helicosphaera aff. *H. seminulum* Bramlette and Sullivan. BRAMLETTE and WILCOXON, 1967, pl. 5, figs. 11-12; Oligocene, Trinidad.
Helicopontosphaera wilcoxoni GARTNER, 1971, pl. 2; Eocene, Blake Plateau. HAQ, 1973, pl. 5, figs. 1-2; Eocene-Oligocene.
Helicopontosphaera lophota (Bramlette and Sullivan). HAQ, 1971c, pl. 10, figs. 8-9; Oligocene, Syria.

Remarks: This species has a central open area spanned by a crossbar that is parallel to the transverse axis or at a slight angle to it. This bar is optically distinct in cross-polarized light. The final whorl flares into a broad flange, which has an abrupt termination. The final flange segments are much wider than those for the remainder of the specimen. This species differs from *Helicopontosphaera seminulum* (Bramlette and Sullivan) in its less rounded outline, normally slightly angled crossbar and distinct flange.

Occurrence: H. wilcoxoni occurs in the upper middle Eocene (Blow's P14) of Alabama.

PLATE 9

Figures Page

1-4. *Micrantholithus angulosus* Stradner and Papp Sample B-30 189
1. Electron micrograph, X5,200
2a. Cross-polarized light, X2,200
2b. Phase contrast, X2,200
3a. Cross-polarized light, X2,200
3b. Phase contrast, X2,200
4. Electron micrograph, X8,700
5-8. *Micrantholithus procerus* Bukry and Bramlette Sample B-30 189
5a. Cross-polarized light, X2,200
5b. Phase contrast, X2,200
6a. Cross-polarized light, X2,200
6b. Phase contrast, X2,200
7a. Cross-polarized light, X2,200
7b. Phase contrast, X2,200
8a. Transmitted light, X2,200 Plan view
8b. Transmitted light, X2,200 Side view

1

2a

2b

3a

3b

4

5a

5b

6a

6b

7a

7b

8a

8b

PLATE 9

HELICOPONTOSPHAERA sp. A
Plate 18, Figure 9

Remarks: This small species of *Helicopontosphaera* has a flattened elliptical outline. The flange is small and only protrudes slightly. A broad double bar crosses the central area at an angle. *Helicopontosphaera* sp. A is the only member of this genus in which the double nature of the crossbar can be discerned in cross-polarized light.

Occurrence: Helicopontosphaera sp. A occurs only in the upper middle Eocene (Blow's P14) of Alabama.

Genus LOPHODOLITHUS
Deflandre 1954
Type species: *Lophodolithus mochlophorus* Deflandre

LOPHODOLITHUS MOCHLOPHORUS
Deflandre 1954

Lophodolithus mochlophorus DEFLANDRE *in* DEFLANDRE and FERT, 1954, pl. 12, figs. 20-23; text-figs. 69-71; Eocene, France. BRAMLETTE and SULLIVAN, 1961, pl. 4, fig. 6; Eocene, California, Texas, France. SULLIVAN, 1964, pl. 6, fig. 9; Paleocene, California. SULLIVAN, 1965, pl. 6, figs. 1-3; Eocene, California. MANIVIT, 1965, pl. 2, fig. 11; Cretaceous, Eocene, France. BUKRY and KENNEDY, 1969, figs. 4-4, 4-5; Eocene, California. PERCH-NIELSEN, 1971b, pl. 38, fig. 1; Eocene, Denmark. LOCKER, 1972, pl. 10, fig. 4; Eocene, Europe.

Remarks: L. mochlophorus is ovoid in outline and the wider end has a large flaring flange. Across the large central opening is a straight slender bar, which is parallel to the short axis. Individual flange segments are visible with the light microscope. *Lophodolithus nascens* Bramlette and Sullivan has a much smaller flange, no visible flange segments in the light microscope, and a more uniformly elliptical outline.

Occurrence: L. mochlophorus occurs in the lower middle Eocene (Blow's P11) of Alabama.

Genus TRANSVERSOPONTIS
Hay, Mohler, and Wade 1966
Type species: *Discolithus obliquipons* Deflandre

TRANSVERSOPONTIS EXILIS
(Bramlette and Sullivan) 1961
Plate 21, Figure 5

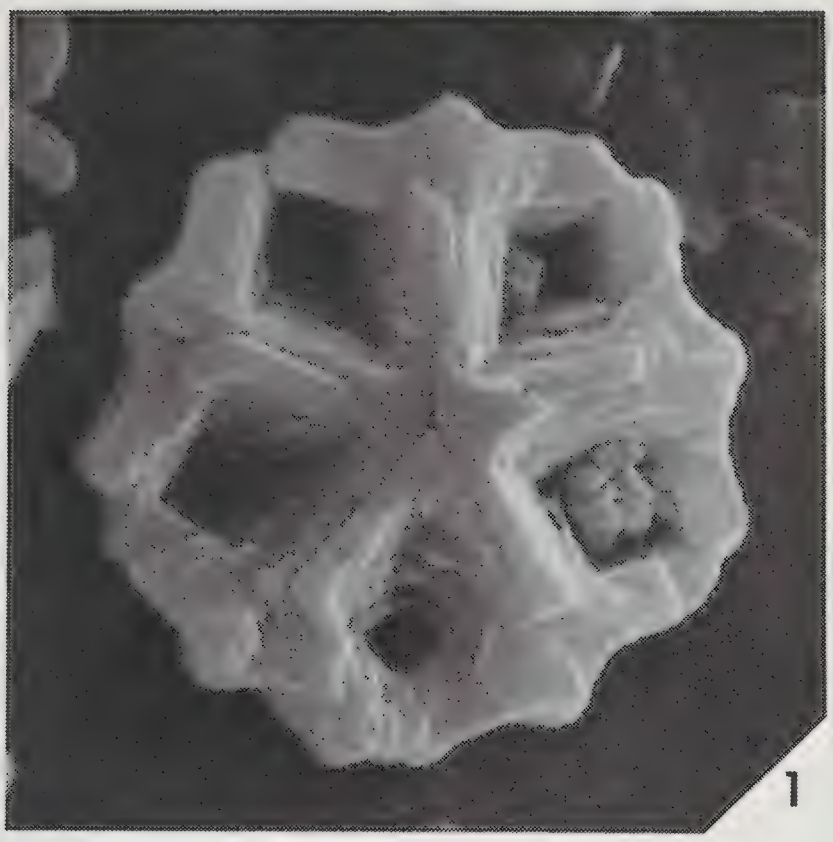
Discolithus exilis BRAMLETTE and SULLIVAN, 1961, pl. 2, fig. 10; Eocene, California. SULLIVAN, 1965, pl. 5, fig. 7; Eocene, California. REINHARDT, 1967, pl. 3, figs. 20, 24; Eocene, Germany.

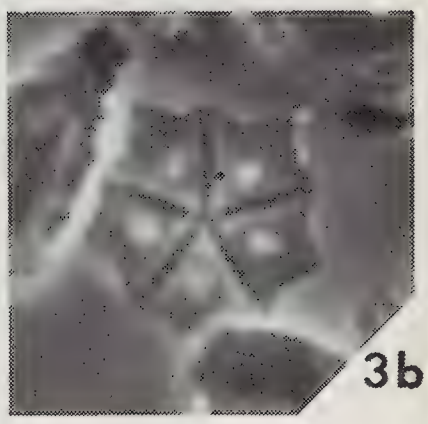
PLATE 10

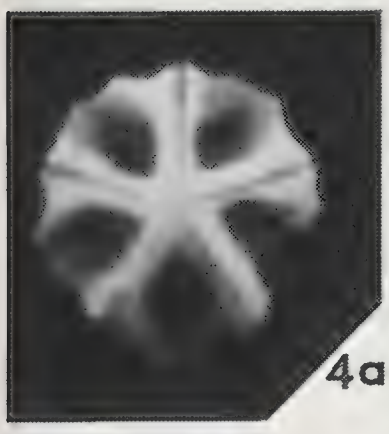
Figures Page

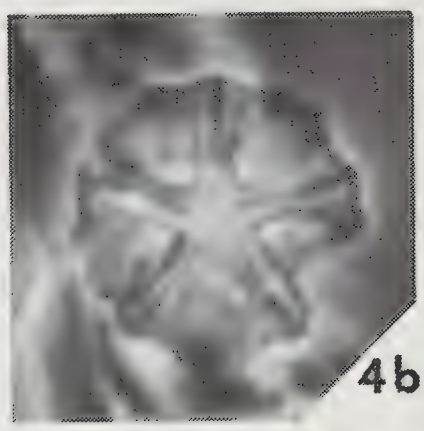
1-5. *Pemma basquense basquense* (Martini) Sample B-30 190
1. Electron micrograph, X5,200
2a. Cross-polarized light, X2,200
2b. Phase contrast, X2,200
3a. Cross-polarized light, X2,200
3b. Phase contrast, X2,200
4a. Cross-polarized light, X2,200
4b. Phase contrast, X2,200
5a. Cross-polarized light, X2,200
5b. Phase contrast, X2,200

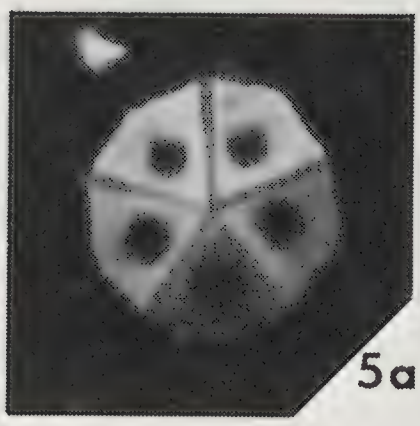
6-9. *Pemma basquense crassum* (Bouché) Sample B-30 191
6a. Cross-polarized light, X2,200
6b. Phase contrast, X 2,200
7a. Cross-polarized light, X2,200
7b. Phase contrast, X2,200
8a. Cross-polarized light, X2,200
8b. Phase contrast, X2,200
9a. Cross-polarized light, X2,200
9b. Phase contrast, X2,200

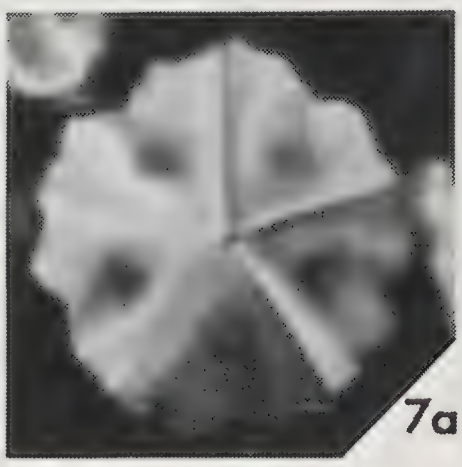












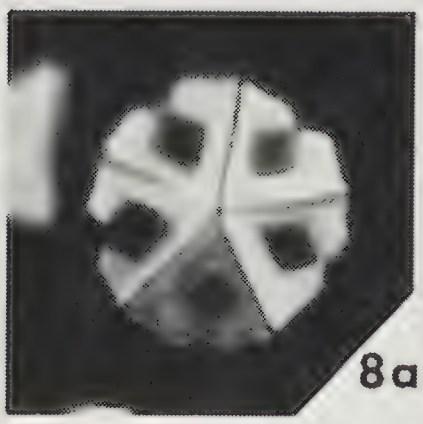


PLATE 10

Discolithus aff. *D. pulcher* (Sullivan). BRAMLETTE and SULLIVAN, 1961, pl. 3, figs. 9-10; Eocene, California.

Transversopontis exilis (Bramlette and Sullivan). PERCH-NIELSEN, 1971b, pl. 27, figs. 3, 5-6; pl. 31, fig. 4; Eocene, Denmark.

Remarks: This discolith has an elliptical base with a high outward sloping wall and two large circular holes in the base. The base, as viewed from both sides, has rods running from the periphery toward the center. These rods can be seen indistinctly under cross-polarized light. The wall laths spiral upward and around the specimens. *T. exilis* lacks the scalloped and perforated pattern of *T. pulcher* (Deflandre). *Transversopontis fimbriatus* (Bramlette and Sullivan) has smaller holes and a different type of wall and basal structure; the walls are higher and there is a thick, flat upper rim.

Occurrence: T. exilis occurs in the middle Eocene (Blow's P11-P14) of Alabama.

TRANSVERSOPONTIS FIMBRIATUS (Bramlette and Sullivan) 1961

Plate 22, Figures 1, 3

Discolithus fimbriatus BRAMLETTE and SULLIVAN, 1961, pl. 3, fig. 1; Eocene, California, Texas. BENEŠOVÁ and HANZLÍKOVÁ, 1962, pl. 3, fig. 12; Miocene, Czechoslovakia. SULLIVAN, 1964, pl. 3, fig. 9; Paleocene, California. SULLIVAN, 1965, pl. 5, figs. 1-3; Eocene, California. Not REINHARDT, 1967, pl. 3, figs. 1, 5.

Koczyia fimbriata (Bramlette and Sullivan). PERCH-NIELSEN, 1971b, pl. 27, fig. 1; pl. 29, figs. 1-2; Eocene, Denmark.

Transversopontis fimbriatus (Bramlette and Sullivan). LOCKER, 1972, pl. 1, fig. 13; Eocene, Europe.

Remarks: This large lopadolith has two circular perforations in its base. The walls rise almost vertically and then spread laterally, forming a wide flat rim. Little Stave Creek specimens appear to have layers of crystals parallel to the periphery, but specimens illustrated by Perch-Nielsen (1971b) have radiating laths. Further study may prove these to be separate species. *Transversopontis pectinatus* (Bramlette and Sullivan) also has two circular perforations, but lacks the broad rim.

Occurrence: T. fimbriatus occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

TRANSVERSOPONTIS OBLIQUIPONS (Deflandre) 1954

Plate 21, Figures 1-4

Discolithus obliquipons DEFLANDRE *in* DEFLANDRE and FERT, 1954, pl. 11, figs. 1-2; Oligocene, New Zealand.

Discolithus pulcher Deflandre. BACHMANN, PAPP, and STRADNER, 1963, pl. 23, fig. 10; Austria.

Zygolithus cf. *Z. obliquipons* (Deflandre). STRADNER, 1964, text-fig. 19.

Discolithus pulcheroides SULLIVAN, 1964, pl. 4, fig. 7; Eocene, California. REINHARDT, 1967, in part; pl. 3, fig. 18; Eocene, Germany.

Discolithina pulchra (Deflandre). LEVIN, 1965, pl. 41, fig. 6; Eocene, Mississippi.

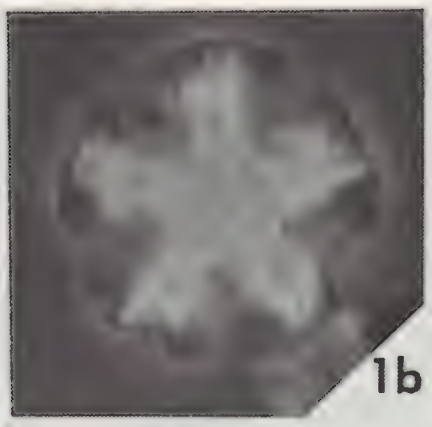
Discolithina cf. *D. pulcheroides* (Sullivan). GARTNER and SMITH, 1967, pl. 6, figs. 1-3; Eocene, Louisiana.

PLATE 11

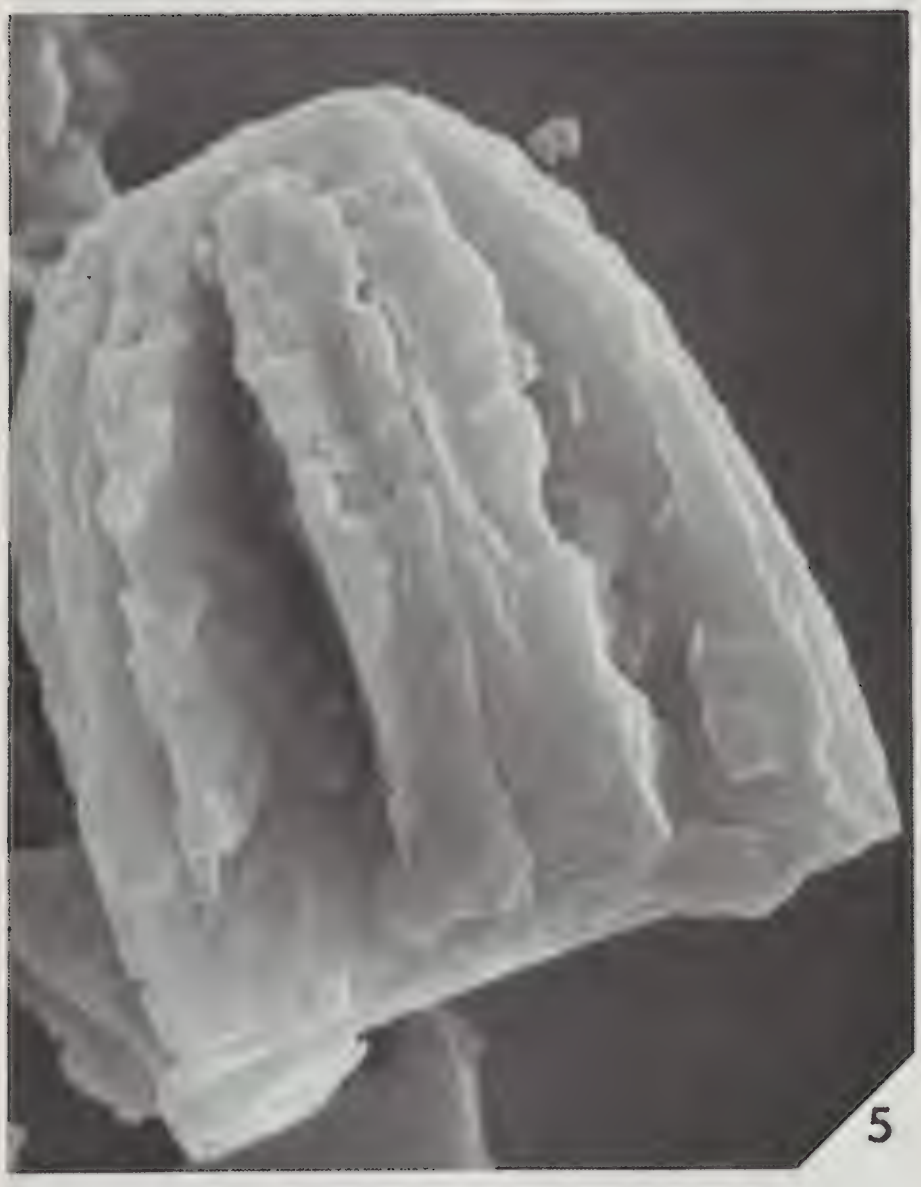
Figures Page

1-7. *Micrantholithus altus* Bybell and Gartner Sample B-30 189
1a. Cross-polarized light, X2,200
1b. Phase contrast, X2,200
2. Electron micrograph, X5,200
3a. Transmitted light, X2,200 Plan view
3b. Transmitted light, X2,200 Side view
4a. Transmitted light, X2,200 Plan view
4b. Transmitted light, X2,200 Side view
5. Electron micrograph, X5,200
6. Electron micrograph, X5,200
7. Electron micrograph, X5,200

1a


1b

2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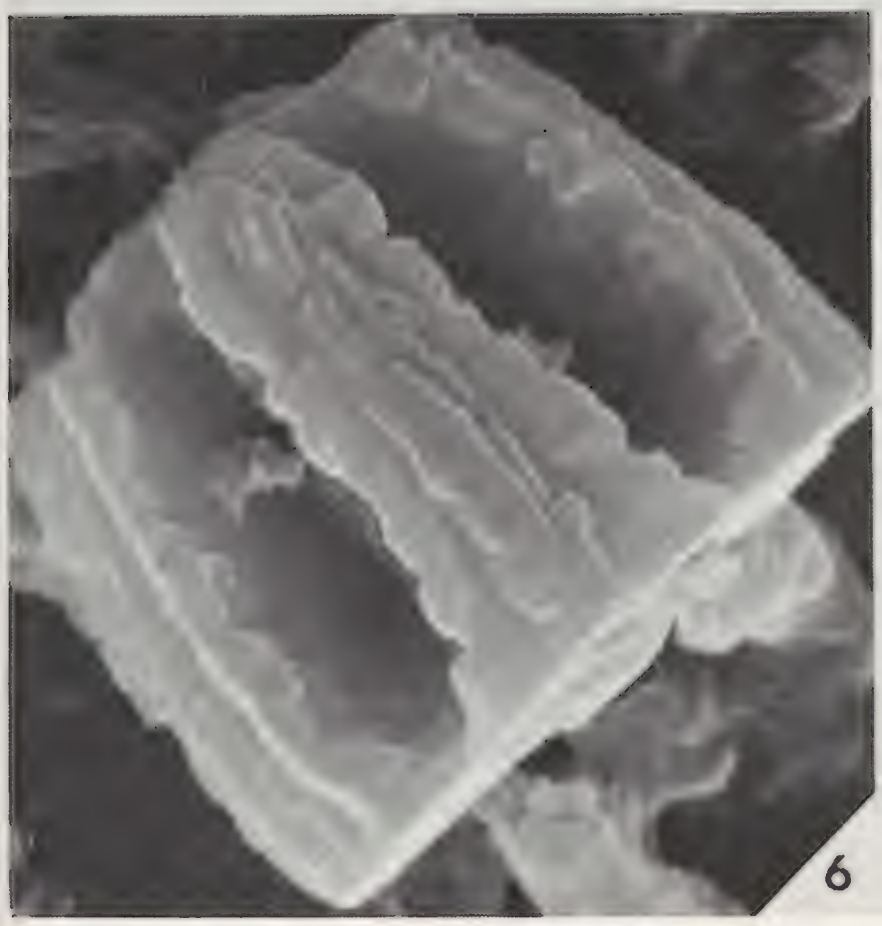
3a

3b

4a

4b


6

7

PLATE 11

Transversopontis obliquipons (Deflandre). HAY, MOHLER, and WADE, 1966, pl. 8, fig. 5; Eocene, USSR. PERCH-NIELSEN, 1967, pl. 3, figs. 6-8; Eocene, Denmark. MARTINI, 1969b, pl. 2, figs. 22-23; Eocene-Oligocene, Switzerland. HODSON and WEST, 1970, pl. 1, fig. 4; pl. 2, fig. 4; Eocene, England. HAQ, 1971b, pl. 7, figs. 5-6; pl. 8, figs. 1-3; pl. 8, figs. 8-9; pl. 17, fig. 2; Eocene-Oligocene, Germany. Not POZARYSKA and LOCKER, 1971, pl. 2, fig. 3. not Locker, 1972, pl. 1, fig. 20.

Discolithina pulcheroides (Sullivan). LEVIN and JOERGER, 1967, pl. 2, fig. 8; Eocene-Oligocene, Alabama. HAQ, 1968, in part; pl. 7, figs. 2-3; Eocene, Germany. STRADNER and EDWARDS, 1968, pl. 38, figs. 6-10; Eocene, New Zealand. MARTINI, 1969b, pl. 1, figs. 9-10; Oligocene, Switzerland.

Transversopontis prava LOCKER, 1967, pl. 2, fig. 5; pl. 1, fig. 1; Oligocene, Germany. PERCH-NIELSEN, 1971b, pl. 33, figs. 1-2, 4-6; Eocene, Denmark.

Discolithus pulchriporus REINHARDT, 1967, in part; pl. 7, fig. 5; Eocene, Germany.

Discolithina obliquipons (Deflandre). Not HAQ, 1968, pl. 7, figs. 4-6; pl. 11, fig. 2.

Discolithus aff. *D. obliquipons* Deflandre. CLOCCHIATTI, 1971, pl. 18, figs. 3-5; Oligocene, Africa.

Transversopontis pulcheroides (Sullivan). PERCH-NIELSEN, 1971b, pl. 33, figs. 3, 7; Eocene, Denmark. SHERWOOD, 1974, pl. 5, figs. 15-16; Eocene, Texas.

Transversopontis pulchra (Deflandre). POZARYSKA and LOCKER, 1971, pl. 2, fig. 5; Eocene, Poland.

Transversopontis pulcher (Deflandre), LOCKER, 1972, pl. 1, figs. 18-19; Eocene, Europe.

Transversopontis pulchriporus (Reinhardt). SHERWOOD, 1974, pl. 5, figs. 17-18; pl. 6, fig. 6; Eocene, Texas.

Remarks: This species has an elliptical rim, which is spanned at an angle by a broadly S-shaped crossbar. Small circular pits are evenly spaced along the inner periphery of the rim and the outer part of the crossbar normally bears a pore on each end. These pores are visible only on the distal surface. Small knobs at the level of the distal surface line the two large openings. On the distal surface the crystallites are arranged in concentric bands, but on the proximal surface the rods radiate outward from the center. The proximal surface is smaller than the distal and in proximal view the outward and upward spiraling laths of the walls are visible. *T. obliquipons* is similar to *Transversopontis pulcher* (Deflandre), but has an angled rather than straight crossbar. There is some variation in this species and the crossbar can be very curved or almost straight. The number of pores normally forms a single row around the periphery, but in some specimens there may be a double row (Plate 21, Figure 3). In some forms the shallow pores are filled in or the pores are so shallow that

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PLATE 12

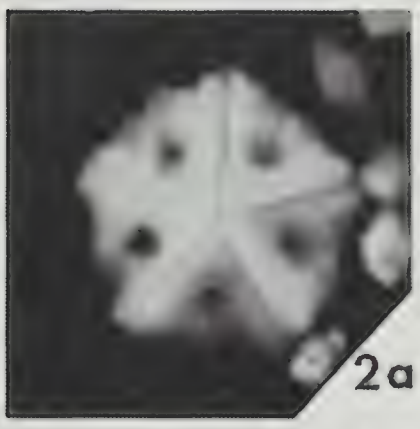
Figures Page

1-6. *Pemma serratum* (Chang) Sample B-30 192
1a. Cross-polarized light, X2,200
1b. Phase contrast, X2,200
2a. Cross-polarized light, X2,200
2b. Phase contrast, X2,200
3a. Cross-polarized light, X2,200
3b. Phase contrast, X2,200
4a. Cross-polarized light, X2,200
4b. Phase contrast, X2,200
5a. Electron micrograph, X5,200
5b. Electron micrograph, X4,800 Tilted specimen
6. Electron micrograph, X4,400

7-8. *Pemma stradneri* (Chang) Sample B-30 192
7a. Cross-polarized light, X2,200
7b. Phase contrast, X2,200
8a. Cross-polarized light, X2,200
8b. Phase contrast, X2,200

1a

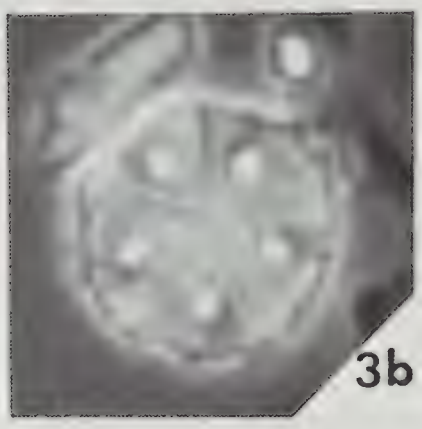
1b

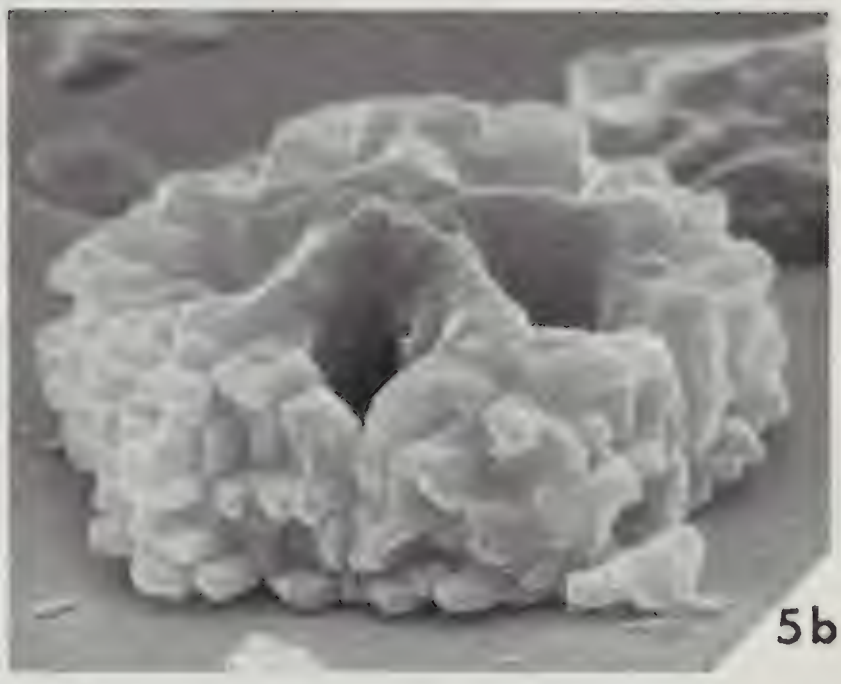

2a

2b

5a

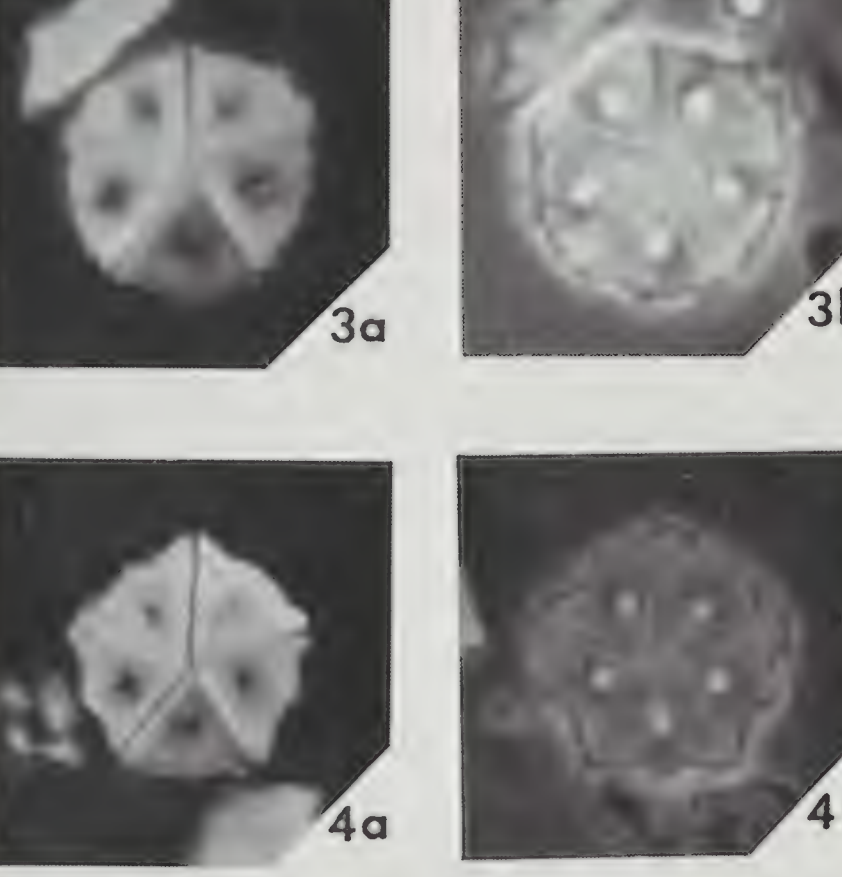
3a


3b


5b

4a

4b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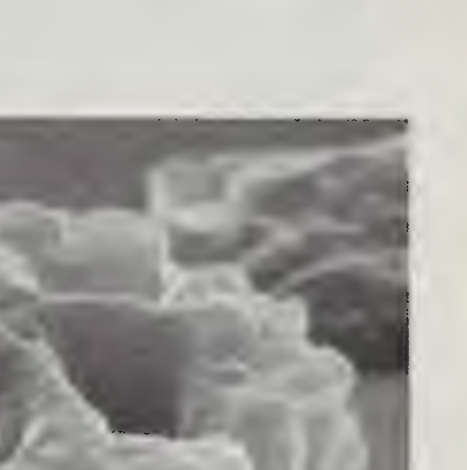
7a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8a

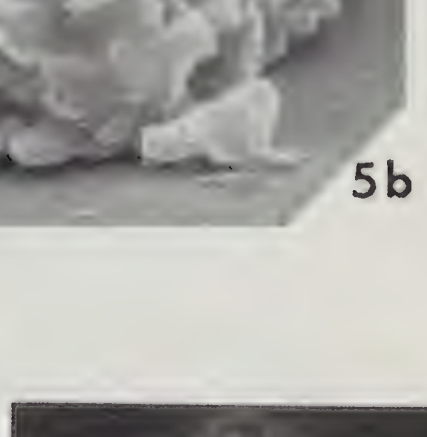
8b

PLATE 12

they cannot be seen with the light microscope.

Occurrence: T. obliquipons occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

Family RHABDOSPHAERACEAE
Lemmermann 1908
Genus BLACKITES
Hay and Towe 1962

Type species: *Discolithus spinosus* Deflandre and Fert

BLACKITES CREBER (Deflandre) 1954
Plate 1, Figures 3-4

Rhabdolithus creber DEFLANDRE *in* DEFLANDRE and FERT, 1954, pl. 12, figs. 31-33; text-figs. 81-82; Eocene, France. BOUCHÉ, 1962, pl. 1, fig. 6; Eocene, France. BYSTRICKÁ, 1963, pl. 1, fig. 13; Eocene, Czechoslovakia.

Rhabdosphaera crebra (Deflandre). BRAMLETTE and SULLIVAN, 1961, pl. 5, figs. 1-3; Eocene, California. HAY and TOWE, 1963, pl. 1, figs. 2-5; pl. 2, figs. 1-5; Eocene, France. SULLIVAN, 1964, pl. 7, fig. 3; Eocene, California. SULLIVAN, 1965, pl. 7, figs. 4-5; Eocene, California. REINHARDT, 1967, pl. 2, fig. 20; pl. 3, figs. 7-8; pl. 7, fig. 1; Eocene, Germany. BUKRY and KENNEDY, 1969, pl. 4, figs. 9-10; Eocene, California. LOCKER, 1972, p. 2, figs. 2-3; Eocene, Europe.

Rhabdosphaera vitrea (Deflandre). HAY and TOWE, 1963, pl. 1, fig. 1; Eocene, France.

Rhabdolithes creber (Deflandre). HODSON and WEST, 1970, pl. 2, figs. 2-3; pl. 3, fig. 3; text-fig. 3; Eocene, Britain.

Blackites spinosus (Deflandre and Fert). PERCH-NIELSEN, 1971b, in part; pl. 44, figs. 3-5, 7-8; Eocene, Denmark.

Blackites creber (Deflandre) SHERWOOD, 1974, pl. 5, figs. 25-26; Eocene, Texas.

Blackites tenuis (Bramlette and Sullivan). SHERWOOD, 1974, in part; pl. 6, fig. 7; Eocene, Texas.

Remarks: the basal disc of *Blackites creber* has four cycles of crystals and is surmounted by a circular tapering stem. There is a distinct collar surrounding the basal part of the stem. In previously illustrated specimens the distal view of the base is almost identical to that of *Blackites spinosus* (Deflandre and Fert), the major difference being in the oblique rather than radiating laths of the second cycle. *B. creber* is rare in Little Stave Creek samples and no distal views were seen to confirm the similarity with *B. spinosus*. However, specimens of *Blackites* sp. aff. *B. creber,* which are common at Little Stave Creek, do closely resemble *B. spinosus*. This four-cycled basal construction is similar for most species in the genus *Blackites* and more diagnostic features for *B. creber* are a distinct flaring collar and only slightly tapering stem. The proximal view of *B. creber,* with only a small portion of the outer rim of crystals visible, has more affinities with *Rhabdosphaera vitrea* (Deflandre) than *B. spinosus*. The remainder of the base is made of imbricate, radiating, wedge-shaped segments. All four segment cycles are visible in a proximal view of *B. spinosus*.

Occurrence: B. creber occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

BLACKITES sp. aff. B. CREBER
(Deflandre) 1954
Plate 1, Figures 1-2

Remarks: Both *Blackites* sp. aff. *B. creber* and *B. creber* (Deflandre) possess an arched

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PLATE 13

Figures Page

1-2. *Pentaster lisbonensis* Bybell and Gartner Sample B-30 192
1a. Electron micrograph, X5,000 11° Tilt
1b. Electron micrograph, X4,400 45° Tilt
2a. Cross-polarized light, X2,200
2b. Interference contrast, X2,200
2c. Transmitted light, X2,200

3. *Orthozygus aureus* (Stradner) Sample B-30 242
3a. Electron micrograph, X8,700 55° Tilt
3b. Electron micrograph, X8,700

1a

1b

2a

2b

2c

3a

3b

PLATE 13

basal plate with four cycles of crystal elements, surmounted by a narrow tapering stem. The proximal views of these species are also similar, with only the outer rim of elements being visible from the distal side. *Blackites* sp. aff. *B. creber,* however, is only one-half the size of *B. creber.* The collar of *Blackites* sp. aff. *B. creber* is formed of two layers of crystallites, one higher on the stem than the other. The plates of the lower layer are offset and at an angle to the upper layer. The collar of *B. creber* also has two layers, but they are aligned and the crystals are all vertically arranged.

Occurrence: Blackites sp. aff. *B. creber* occurs in the upper middle Eocene (Blow's P14) of Alabama.

BLACKITES SPINOSUS
(Deflandre and Fert) 1954
Plates 2-3

Discolithus spinosus DEFLANDRE and FERT. 1952, nomen nudum; text-fig. 4. DEFLANDRE and FERT, 1954, pl. 14, figs. 13-15; Eocene, France; Oligocene, New Zealand.

Blackites spinosus (Deflandre and Fert). HAY and TOWE, 1962, pl. 4, figs. 5; Eocene, France. BLACK, 1965, fig. 17; Paleocene, Denmark. HODSON and WEST, 1970, pl. 2, fig. 5; text-fig. 3; Eocene, Britain. HAQ, 1971a. pl. 5, figs. 8-9; Eocene, Pakistan. HAQ, 1971b, pl. 11, figs. 1-2; pl. 17, fig. 7; in part; Eocene, Germany. PERCH-NIELSEN, 1971b, pl. 45, figs. 6-7; Eocene, Denmark.

Rhabdosphaera spinula LEVIN, 1965, pl. 42, fig. 3; Eocene, Mississippi. GARTNER and SMITH, 1967, pl. 1, figs. 1-2; Eocene, Mississippi. HAQ, 1967, pl. 3, figs. 1-3; Eocene, Pakistan. LEVIN and JOERGER, 1967, pl. 2, fig. 15; Eocene-Oligocene, Alabama. MARTINI, 1969b, pl. 3, figs. 28-29; Eocene-Oligocene, Germany. HAQ, 1971, pl. 10, fig. 14; Eocene, Pakistan. POZARYSKA and LOCKER, 1971, pl. 2, fig. 28; Eocene, Poland. LOCKER, 1972, pl. 2, fig. 13; pl. 3, fig. 9; Eocene, Europe.

Blackites amplus Roth and Hay. HAY, *et al.,* 1967, pl. 7, fig. 10; Oligocene, Blake Plateau. ROTH, 1970, pl. 7, fig. 6; Oligocene, Blake Plateau, Alabama, Barbados, Trinidad, Germany, Belgium, Italy. SHERWOOD, 1974, pl. 6, figs. 9-10; pl. 7, figs. 3-4; Eocene, Texas.

Rhabdosphaera recta (Deflandre). HAQ, 1968, pl. 9, fig. 8; pl. 11, figs. 17-18; Eocene, Germany.

Blackites rectus (Deflandre). STRADNER and EDWARDS, 1968, in part; pl. 30, figs. 1-4, Eocene, New Zealand.

Blackites spinulus (Levin). ROTH, 1970, pl. 8, fig. 4; Oligocene, Germany, Alabama.

Blackites tenuis (Bramlette and Sullivan). SHERWOOD, 1974, in part; pl. 5, figs. 19-22; pl. 6, fig. 5; Eocene, Texas.

Remarks: This rhabdolith has a long, normally uniformly tapering, circular stem which is attached to a basal shield with four cycles of crystal segments. The outer cycle consists of large, slightly overlapping, trapezoidal crystals and a series of radiating laths forms the second cycle. The third cycle consists of inclined and imbricate crystals which are arranged around an inner cycle. In cross-polarized light these third cycle crystals have a distinctive swasticoid extinction pattern. The inner cycle has similar crystals, but they differ in their orientation, are higher, and grade directly into the stem. The three outer cycles are visible from the proximal side, but in *Blackites creber* (Deflandre)

PLATE 14

Figures Page

1-2. *Chiasmolithus solitus* (Bramlette and Sullivan) 193
1. Electron micrograph, X8,700 Sample B-30
2a. Cross-polarized light, X2,200 Sample B-12
2b. Phase contrast, X2,200

3. *Chiasmolithus titus* Gartner Sample B-30 194
3a. Cross-polarized light, X2,200
3b. Phase contrast, X2,200

4-6. *Campylosphaera dela* (Bramlette and Sullivan) Sample B-30 193
4a. Cross-polarized light, X2,200
4b. Phase contrast, X2,200
5. Electron micrograph, X8,700 Distal view
6. Electron micrograph, X10,400 Proximal view

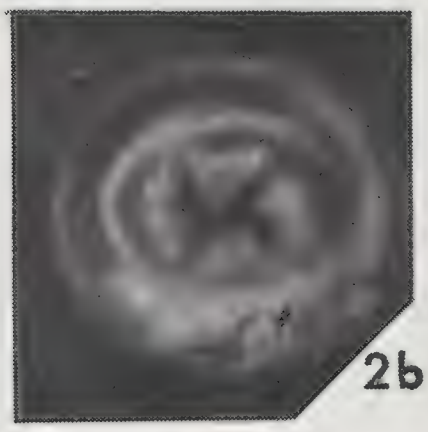
1

4a

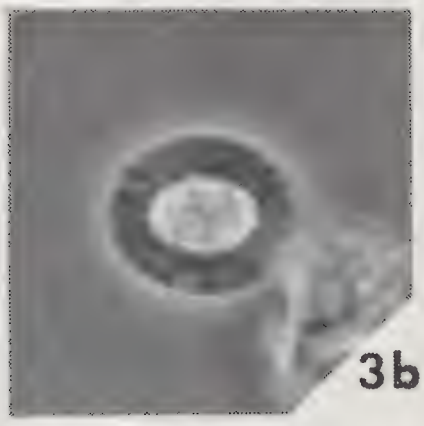
4b

5

2a


2b

3a


3b

6

PLATE 14

only the outer cycle is visible. Specimens of this species are often incomplete; parts of the stem or the entire stem may be broken off and, frequently, the outer two rings of the crystals of the base are missing. *B. creber* has a more pronounced collar which is distinct and flares out from the stem. The collar of *B. spinosus* tapers into the stem.

Occurrence: B. spinosus occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

BLACKITES TENUIS
(Bramlette and Sullivan) 1961 n. comb.
Plate 4

Rhabdosphaera tenuis BRAMLETTE and SULLIVAN, 1961, pl. 5, fig. 14; Eocene, California. BENEŠOVÁ and HANZLÍKOVÁ, 1962, pl. 4, fig. 2; Eocene, Czechoslovakia. SULLIVAN, 1964, pl. 7, fig. 4; Eocene, California. SULLIVAN, 1965, pl. 7, fig. 10; Eocene, California. LEVIN and JOERGER, 1967, pl. 2, fig. 16; Eocene-Oligocene, Alabama. MARTINI, 1969b, pl. 3, figs. 30-31; Eocene-Oligocene, Germany. HAQ, 1971b, pl. 5, fig. 14; pl. 11, fig. 3?; Eocene-Oligocene, Germany. POZARYSKA and LOCKER, 1971, pl. 2, fig. 27; Eocene, Poland. LOCKER, 1972, pl. 3, figs. 1-2; Eocene, Europe.

Rhabdolithes tenuis (Bramlette and Sullivan). Not HODSON and WEST, 1970, pl. 3, fig. 1.

Blackites incompertus ROTH, 1970, pl. 7, fig. 5; pl. 8, figs. 1-2; Oligocene, Alabama, Germany.

Remarks: The base of this rhabdolith contains several cycles of elements and is surmounted by a very long tapering stem. The stem rises vertically from the base for one-third of its length and then tapers to a point. In some specimens there is a slight thickening of the stem one-third of its length from the base, followed by tapering. According to Roth (1970), the base consists of an outer cycle of trapezoidal elements, a cycle of strongly imbricate plates and an inner cycle of square crystals which are above the basal plate and quite distinct in side view. There is no collar and the stem rises directly from this inner cycle of elements. The distal view is similar to that of *Blackites spinosus* (Deflandre and Fert) and *Blackites creber* (Deflandre), but lacks a cycle of radiating laths and a collar. In proximal view the entire outer cycle is visible, as it is in *B. spinosus,* suggesting that the inner cycles also may be visible. Specimens of *B. creber,* which have only two cycles visible in proxi-

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PLATE 15

Figures Page

1-3. *Reticulofenestra umbilica* (Levin) Sample B-30 197
1. Electron micrograph, X5,200 Proximal view
2. Electron micrograph, X5,200 Distal view
3a. Cross-polarized light, X2,200
3b. Phase contrast, X2,200

4. *Reticulofenestra hillae* Bukry and Percival Sample B-30 197
4a. Cross-polarized light, X2,200
4b. Phase contrast, X2,200

5. *Reticulofenestra bisecta* (Hay, Mohler, and Wade) Sample B-30 197
5a. Cross-polarized light, X2,200
5b. Phase contrast, X2,200

6. *Coccolithus sarsiae* Black Sample B-30 194
6a. Cross-polarized light, X2,200
6b. Phase contrast, X2,200

7. *Markalius inversus* (Deflandre) Sample B-19 196
7a. Cross-polarized light, X2,200
7b. Phase contrast, X2,200

8. *Goniolithus fluckigeri* Deflandre Sample B-30 200
8a. Phase contrast, X2,200
8b. Cross-polarized light, X2,200

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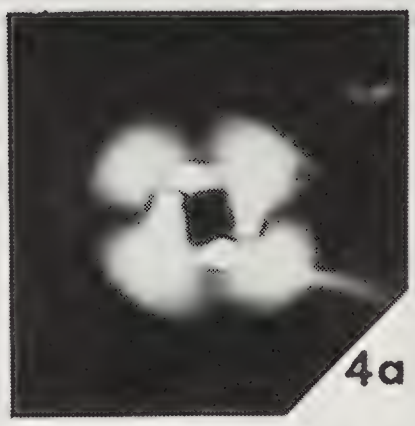
2

3a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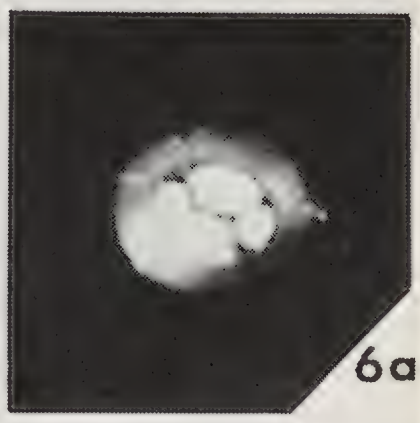
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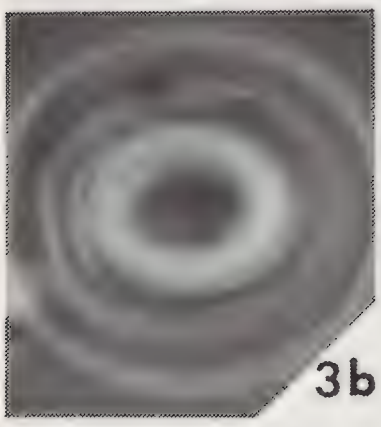
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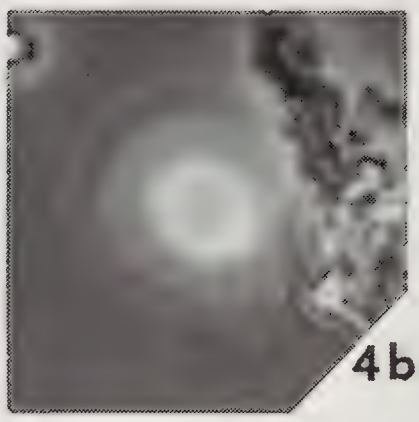
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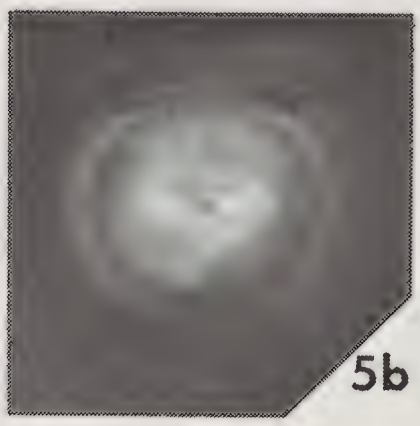
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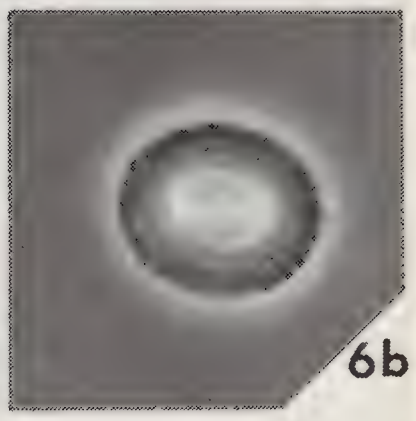
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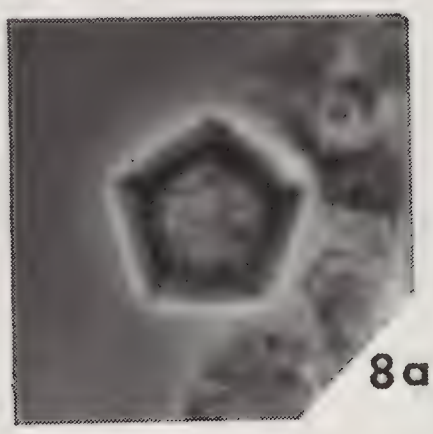
8a

7b

8b

PLATE 15

mal view, expose very little of the outer ring. In many cases the outer cycle of basal crystals is broken off.

Occurrence: B. tenuis occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

BLACKITES TROCHOS n.sp.

Plate 6

Description: This unusual rhabdolith has a circular base of four cycles of elements surmounted by approzimately twelve struts which spiral sinistrally upward and support a broad, hollow stem. The base consists of an outer cycle of trapezoidal segments, a cycle of radiating laths, and a third cycle of imbricate and inclined crystals. A fourth cycle of crystals, similar to the third, but inclined in the opposite direction, rises upward and outward from the base. This cycle forms the base for the struts. The stem is constructed of more or less equidimensional elements, rather than the long laths typical of the stems of most rhabdoliths. All observed specimens had broken stems and the length and amount of taper of the stem is unknown.

Occurrence: Blackites trochos occurs in the upper middle Eocene (Blow's P14) of Alabama.

BLACKITES sp. A

Plate 5, Figure 4

Remarks: This species was not seen with the electron microscope, and it is not possible to describe its construction in detail, although there appears to be some similarity to *Blackites* sp. B. Specimens of *Blackites* sp. A have a large, lower base which is surmounted by an outward extending structure similar to the fourth cycle of elements of *Blackites trochos,* n. sp. A large tubular stem rises from this area and tapers abruptly to a sharp point. *Blackites* sp. A is similar at first glance to *Rhabdosphaera morionum* (Deflandre), but the latter species lacks the complex basal structure and stem and is more bulbous in its upper portion than *Blackites* sp. A.

Occurrence: Blackites sp. A was found in the upper middle Eocene (Blow's P14) of Alabama.

Genus RHABDOSPHAERA
Haeckel 1894
Type species: *Rhabdosphaera claviger* Murray and Blackman

RHABDOSPHAERA VITREA
(Deflandre) 1954
Plate 5, Figures 1-3

PLATE 16

Figures — Page

1-3. *Cycloccolithina reticulata* (Gartner and Smith) Sample B-30 195
1. Electron micrograph, X10,400 Proximal view
2a. Cross-polarized light, X2,200
2b. Phase contrast, X2,200
3a. Cross-polarized light, X2,200
3b. Phase contrast, X22 00

4-5. *Cyclococcolithina formosa* (Kamptner) Sample B-30 195
4a. Cross-polarized light, X2,200
4b. Phase contrast, X2,200
5. Electron micrograph, X8,700 Distal view

6-7. *Daktylethra punctulata* Gartner Sample B-30 238
6. Electron micrograph, X8,700
7a. Cross-polarized light, X2,200
7b. Phase contrast, X2,200

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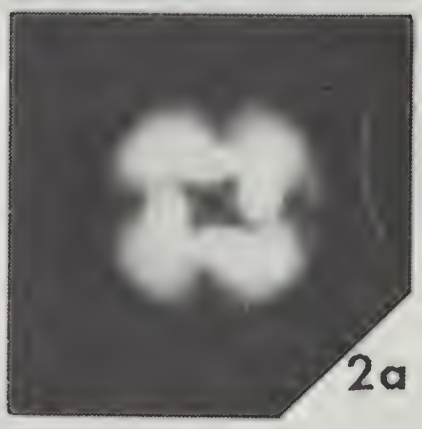
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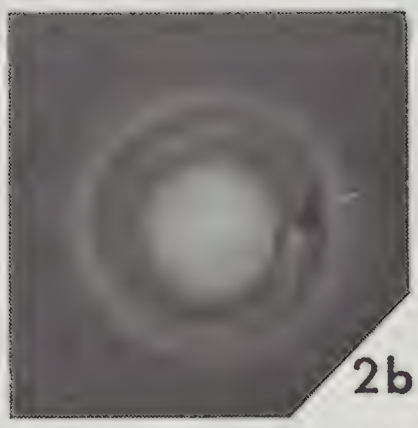
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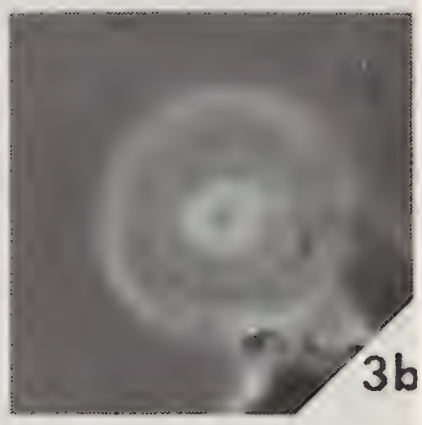
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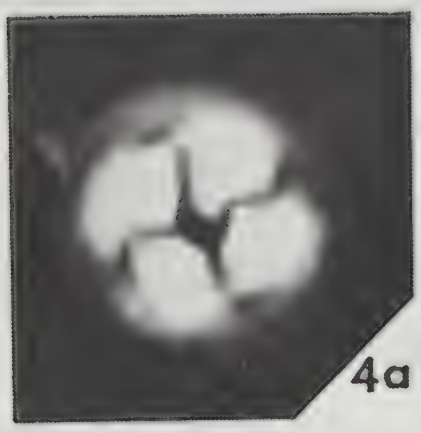
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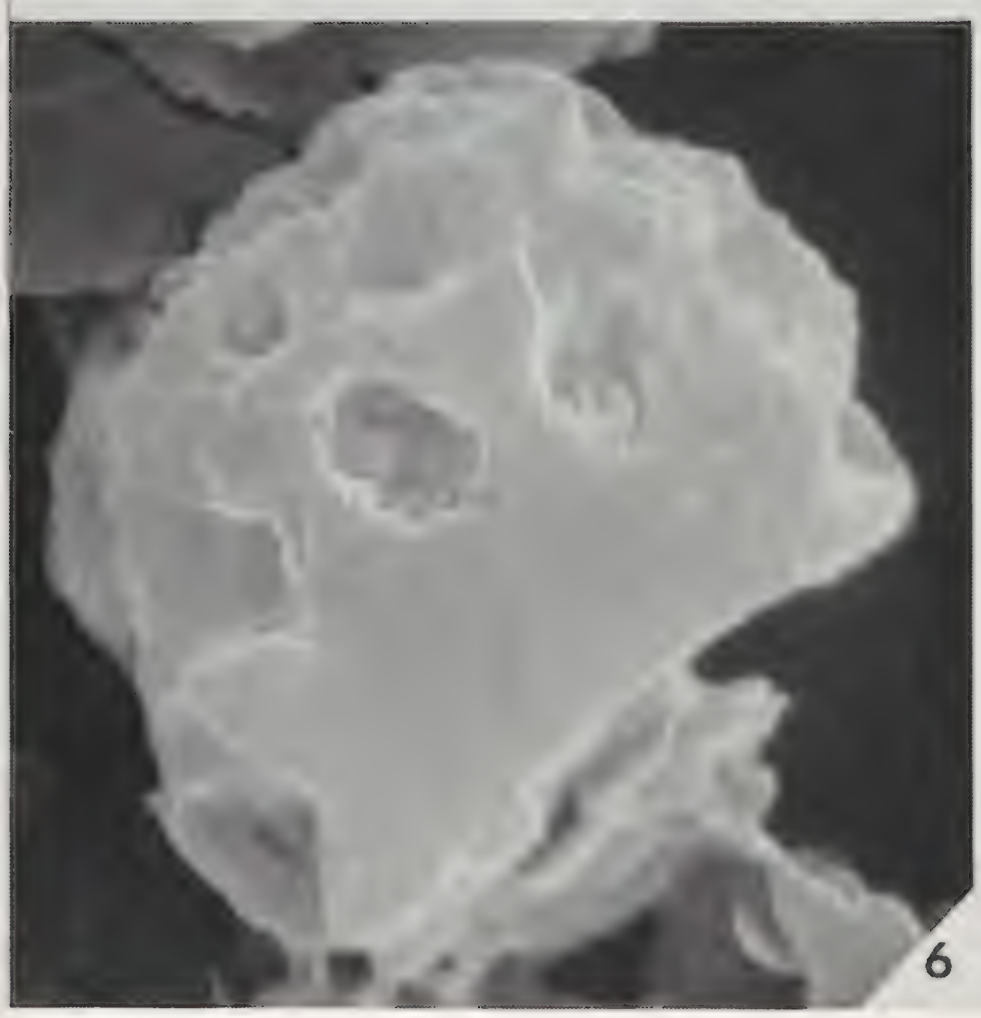
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7a

7b

PLATE 16

Rhabdolithus vitreus DEFLANDRE *in* DEFLANDRE and FERT, 1954, pl. 12, figs. 28-29; text-figs. 83-84; Eocene, France. PERCH-NIELSEN, 1971b, pl. 46, figs. 1-6, 9; Eocene, Denmark.

Rhabdosphaera vitrea (Deflandre). BRAMLETTE and SULLIVAN, 1961, pl. 5, figs. 16-17; Eocene, California. Not HAY and TOWE, 1963, pl. 1, fig. 1. Not LEVIN and JOERGER, 1967, pl. 2, fig. 18. MARTINI, 1969b, pl. 3, figs. 32-33; Eocene, Germany. ROTH, 1970, pl. 8, fig. 6; pl. 9, fig. 1; Oligocene, Alabama, Germany. LOCKER, 1972, pl. 2, figs. 14-16; pl. 3, fig. 9; Eocene, Europe.

Remarks: The base of this rhabdolith consists of an outer rim of wedge-shaped elements that rests upon an inner whorl of small irregularly-shaped pieces. On the proximal side only a very small portion of this rim projects beyond the inner whorl and is visible. Four buttresses rise from the inner area and support a slender slightly tapering stem. In side view as seen through a light microscope, the buttresses appear to be a thick protruding collar which rests on the basal plate. In side view the struts flare out slightly unlike *Blackites creber* (Deflandre) in which the collar is essentially parallel to the stem and positioned much closer to it. The base of *R. vitrea* has only two cycles of elements but *B. creber* has a much more complex basal disc containing four cycles.

Occurrence: R. vitrea occurs in the upper middle Eocene (Blow's P14) of Alabama.

Family SPHENOLITHACEAE Deflandre 1952

Genus SPHENOLITHUS Deflandre 1952

Type species: *Sphenolithus radians* Deflandre

SPHENOLITHUS MORIFORMIS (Bronimann and Stradner) 1960

Plate 23, Figure 2

Nannoturbella moriformis BRÖNNIMANN and STRADNER, 1960, text-figs. 11-16; Eocene, Cuba.

Sphenolithus pacificus MARTINI, 1965, pl. 36, figs. 7-10; Miocene, Trinidad, Pacific. MARTINI, 1971b, pl. 2, figs. 13-14; Eocene-Miocene, Switzerland.

Sphenolithus moriformis (Brönnimann and Stradner). BRAMLETTE and WILCOXON, 1967, pl. 3, figs. 1-6; Oligocene-Miocene, Trinidad. RADOMSKI, 1968, pl. 43, figs. 19-20; Paleocene-Miocene, Poland. ROTH, 1970, pl. 14, figs. 3-4; Eocene-Oligocene. BUKRY, 1971, pl. 4, fig. 6; Miocene, Pacific. HAQ, 1971b, pl. 13, figs. 9-10; Eocene-Oligocene, Germany. HAQ, 1971c, pl. 1, figs. 7, 14, 25-26; pl. 2, figs. 9-10; pl. 3, figs. 5-9; Oligocene, Syria. HAQ and LIPPS, 1971, pl. 5, figs. A-B; Oligocene, Pacific. PERCH-NIELSEN, 1971b, pl. 49, figs. 5-10; Eocene, Denmark. ROTH, FRANZ, and WISE, 1971, pl. 5, figs. 4-6; Oligocene, Blake Plateau. PERCH-NIELSEN, 1972, pl. 16, figs. 1, 4-5;

PLATE 17

Figures — Page

1-2. *Discoaster elegans* Bramlette and Sullivan 199
1. Electron micrograph, X5,200 Sample B-30
2a. Transmitted light, X2,200 Sample B-30
2b. Phase contrast, X2,200

3. *Discoaster barbadiensis* Tan Sin Hok Sample B-12 198
3a. Cross-polarized light, X2,200
3b. Phase contrast, X2,200

4. *Discoaster nodifer* (Bramlette and Riedel) Sample B-30 199
4a. Transmitted light, X2,200
4b. Phase contrast, X2,200

5. *Discoaster saipanensis* Bramlette and Riedel Sample B-30 200
5a. Transmitted light, X2,200
5b. Phase contrast, X2,200

6-7. *Discoaster* sp. A Sample B-30 200
6a. Transmitted light, X2,200
6b. Phase contrast, X2,200
7. Electron micrograph, X5,200

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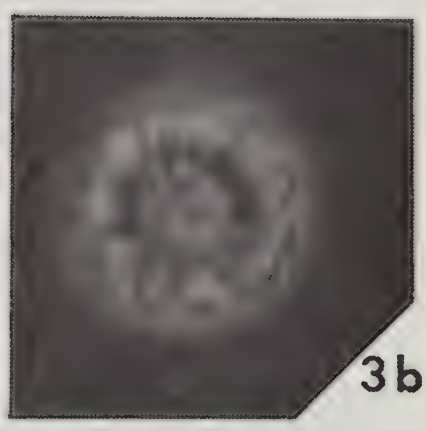
2a

2b

3a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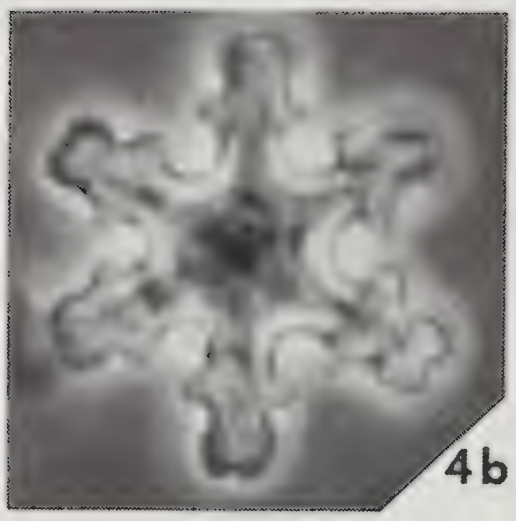
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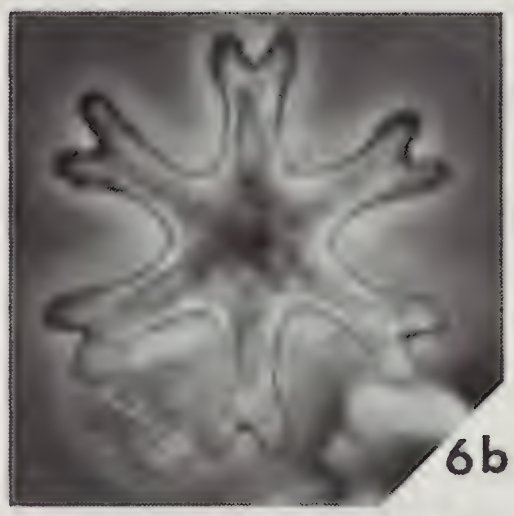
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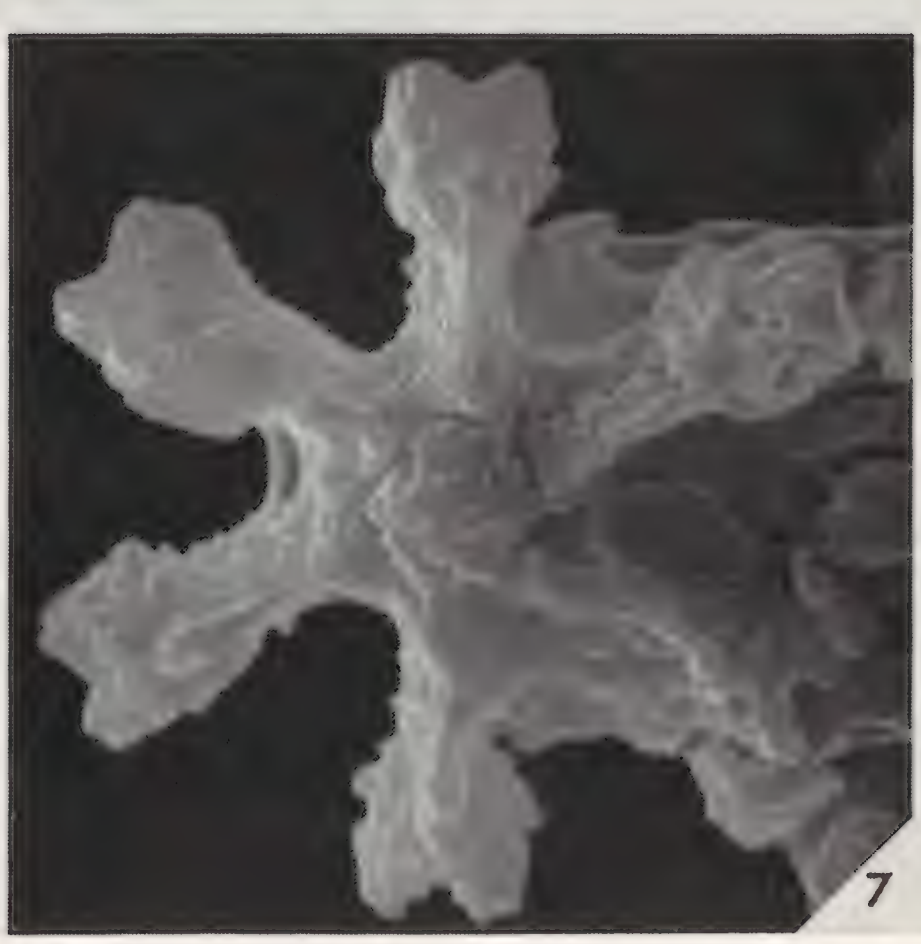
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PLATE 17

Miocene, Atlantic. SHERWOOD, 1974, pl. 7, fig. 26; Eocene, Texas.

Sphenolithus spiniger BUKRY, 1971, pl. 6, figs. 10-12; pl. 7, figs. 1-2; Eocene, Pacific.

Remarks: The basal portion of this species has several radiating elements above which numerous wedge-shaped elements extend outward in an irregular radiate pattern. The apical spines are approximately the same length as the lateral elements, giving the species a bulbous form similar to a beehive. Some specimens found at Little Stave Creek have a less rounded outline and a more pronounced apical spine and more closely resemble the Miocene forms which grade into *Sphenolithus abies* Deflandre.

Occurrence: S. moriformis occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

SPHENOLITHUS RADIANS
Deflandre 1952
Plate 23, Figure 1

Sphenolithus radians DEFLANDRE *in* GRASSÉ, 1952, text-figs. 343, 363; Eocene, France. DEFLANDRE and FERT, 1954, pl. 12, figs. 36-38; text-figs. 109-112; Eocene, France. MANIVIT, 1959, pl. 3, figs. 9-10; Eocene, Africa, France. BRAMLETTE and SULLIVAN, 1961, pl. 14, figs. 6-8; Eocene, California. SULLIVAN, 1964, pl. 9, fig. 10; Paleocene, California. SULLIVAN, 1965, pl. 11, fig. 3; Eocene, California. RADOMSKI, 1968, pl. 46, fig. 14; Paleocene-Miocene, Poland. CLOCCHIATTI, 1971, pl. 23, fig. 5; Miocene, Africa. HAQ, 1971a, pl. 10, fig. 8; Paleocene, Persia; Eocene, Pakistan. PERCH-NIELSEN, 1971b, pl. 47, figs. 1-9; pl. 48, figs. 1-7; Eocene, Denmark. ROTH, FRANZ, and WISE, 1971, pl. 1, figs. 1-2; Eocene, Blake Plateau. BRATU and GHETA, 1972, pl. 4, figs. 46-47; Eocene, Czechoslovakia. ELLIS, LOHMAN, and WRAY, 1972, pl. 9, fig. 3; Pliocene, Gulf of Mexico. Not PERCH-NIELSEN, 1972, pl. 17, fig. 4; Eocene, Atlantic. LOCKER, 1972, pl. 11, figs. 3-4; Eocene, Europe. SHERWOOD, 1974, pl. 9, figs. 3-4; Eocene, Texas.

Sphenolithus cf. *S. radians* Deflandre. HAQ, 1971a, pl. 10, fig. 9; Eocene, Pakistan.

PLATE 18

Figures — Page

1-2. *Zygolithus dubius* Deflandre 236
1. Electron micrograph, X8,700 Sample B-30
2a. Cross-polarized light, X2,200 Sample B-28
2b. Phase contrast, X2,200

3. *?Zygolithus dubius* Deflandre Sample B-12 236
3a. Cross-polarized light, X2,200
3b. Phase contrast, X2,200

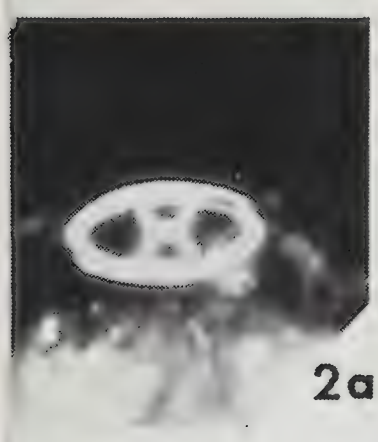
4. *Helicopontosphaera compacta* (Bramlette and Wilcoxon) 212
4a. Cross-polarized light, X2,200 Sample B-30
4b. Phase contrast, X2,200

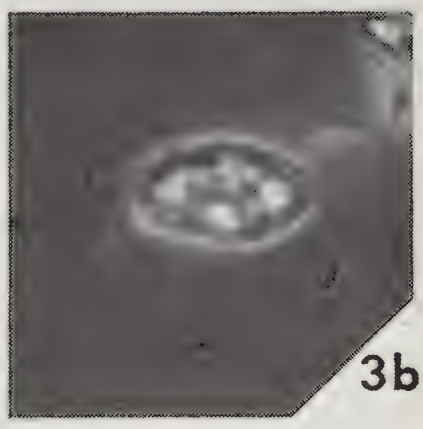
5. *Helicopontosphaera seminulum* (Bramlette and Sullivan) 214
5a. Cross-polarized light, X2,200 Sample B-30
5b. Phase contrast, X2,200

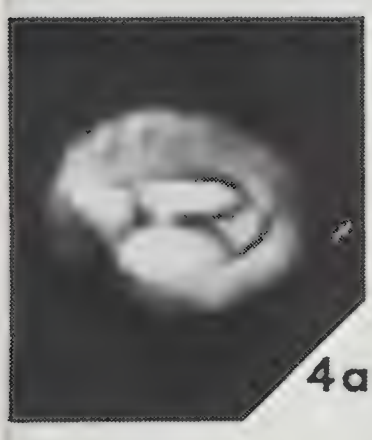
6-7. *Helicopontosphaera wilcoxoni* Gartner 216
6a. Cross-polarized light, X2,200 Sample B-30
6b. Phase contrast, X2,200
7a. Cross-polarized light, X2,200 Sample B-28
7b. Phase contrast, X2,200

8. *Helicopontosphaera reticulata* (Bramlette and Wilcoxon) 214
8a. Cross-polarized light, X2,200 Sample B-30
8b. Phase contrast, X2,200

9. *Helicopontosphaera* sp. A Sample B-28 218
9a. Cross-polarized light, X2,200
9b. Phase contrast, X2,200







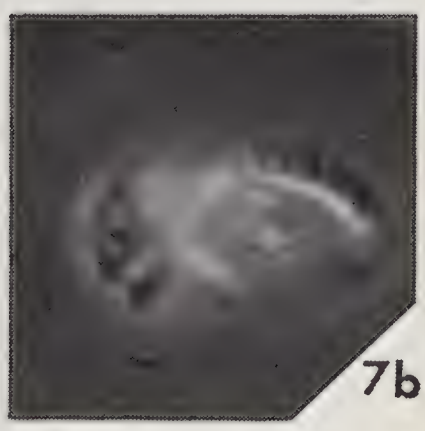


PLATE 18

Remarks: The base of this species is constructed of radiating wedge-shaped elements and is surmounted by several blade-like segments that rise to form a non-bifurcating apical spine. *Sphenolithus heteromorphus* Deflandre has a longer narrower spine, which is rounded instead of blade-like. *S. radians* has a taller narrower base and thinner spines than *Sphenolithus pseudoradians* Bramlette and Wilcoxon. Under the light microscope, however, *S. radians* and *S. pseudoradians* are indistinguishable.

Occurrence: S. radians occurs in the upper middle Eocene (Blow's P14) of Alabama.

Family SYRACOSPHAERACEAE
Lemmermann 1908
Genus CEPEKIELLA Roth 1970
Type species: *Cepekiella elongata* Roth

CEPEKIELLA LUMINA
(Sullivan) 1965 n. comb.

Plate 5, Figures 5-6

Cyclococcolithus luminis SULLIVAN, 1965, pl. 3, fig. 9; Eocene, California. LEVIN and JOERGER, 1967, pl. 1, fig. 12; pl. 4, fig. 17; Eocene-Oligocene, Alabama. REINHARDT, 1967, pl. 1, figs. 17-18; pl. 2, fig. 10; Eocene, Germany. POZARYSKA and LOCKER, 1971, pl. 2, fig. 14; Eocene, Poland. LOCKER, 1972, pl. 7, figs. 13-14; Eocene, Europe.

Blackites hayi Stradner. STRADNER and EDWARDS, 1968, in part; pl. 31, fig. 6; text-fig. 5; Eocene, New Zealand.

Cepekiella hayi (Stradner). ROTH, 1970, pl. 11, fig. 3; Oligocene, Alabama, Germany.

Remarks: The distal shield of *C. lumina* consists of an outer cycle of trapezoidal segments and an inner domed structure of crystal laths that spiral inward and upward, terminating in a slender stem. Short angular struts connect the distal shield with the smaller proximal shield. This proximal shield is often partially or completely broken off from the distal shield and the stem may also be missing. The outer cycle of the distal shield may be broken off. *Cepekiella elongata* Roth has a more elliptical base and the stem is not centrally located on the base.

Occurrence: C. lumina occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

Family ZYGOLITHACEAE Noël 1965
Genus ZYGOLITHUS Kamptner 1949
Type species: *Zygolithus dubius* Deflandre

ZYGOLITHUS DUBIUS
Deflandre 1954
Plate 18, Figures 1-2

Zygolithus dubius DEFLANDRE *in* DEFLANDRE and FERT, 1954, text-figs. 43-44; Eocene, France. MARTINI, 1958, in part; pl. 1, fig. 1a, 1c; Eocene, Germany. MANIVIT, 1959, in part; pl. 1, fig. 4; Eocene, Africa, France. BALDIBEKE, 1960, pl. 14, fig. 4; Oligocene-Miocene, Hungary. MARTINI, 1960, pl. 11, fig. 39; Oligocene, Germany. BRAMLETTE and SULLIVAN, 1961, pl. 6, figs. 12-14; Eocene, California. BENEŠOVÁ and HANZLÍKOVÁ, 1962, pl. 2, fig. 12; pl. 4, fig. 15; Eocene, Miocene, Czechoslovakia. Not BOUCHE, 1962, pl. 1, fig. 5. BYSTRICKÁ, 1963, pl. 1, fig. 14; Eocene, Czechoslovakia. BACHMANN, PAPP

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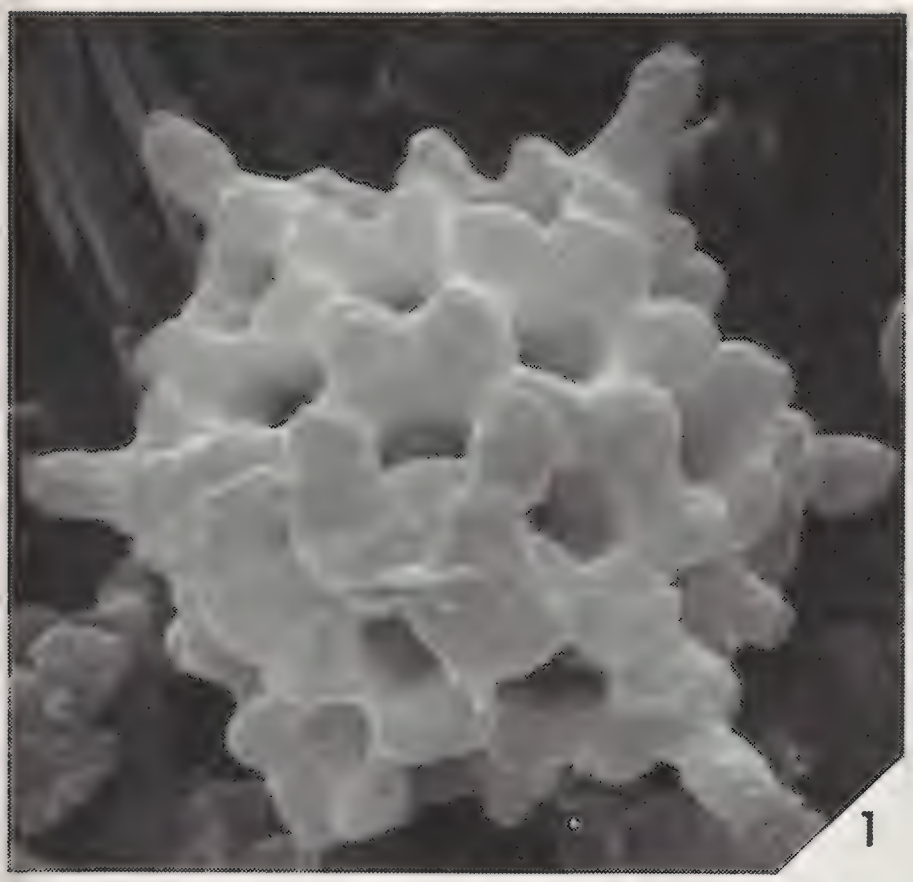
1, 3-4. *Lithostromation operosum* (Deflandre) Sample B-30 202
1. Electron micrograph, X5,200
3a. Transmitted light, X2,200
3b. Phase contrast, X2,200
4. Electron micrograph, X4,400

2. *Lithostromation simplex* (Klumpp) Sample B-15 204
2a. Transmitted light, X2,200
2b. Phase contrast, X2,200

5. *Lithostromation reginum* (Stradner) Sample B-30 204
5. Electron micrograph, X5,200

6. *Lithostromation perdurum* Deflandre Sample B-28 202
6. Phase contrast, X2,200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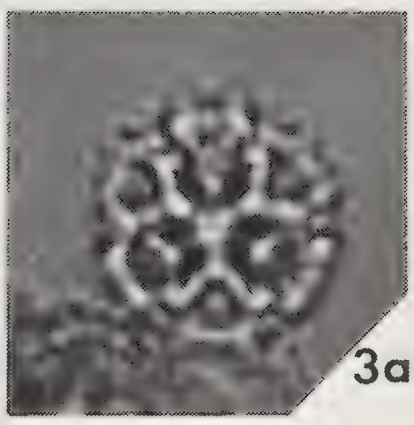
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PLATE 19

and STRADNER, 1963, pl. 24, fig. 5. LOCKER, 1965, pl. 2, fig. 9; Eocene, Germany. PERCH-NIELSEN, 1967, pl. 5, figs. 13-14; Eocene, Denmark. REINHARDT, 1967, pl. 4, figs. 14-16, 19-20; Eocene, Germany. LOCKER, 1968, pl. 2, fig. 19; Eocene, Germany. BALDI-BEKE, 1971, pl. 1, figs. 14-16; Eocene, Hungary. POZARYSKA and LOCKER, 1971, pl. 2, fig. 6; Eocene, Poland. LOCKER, 1972, pl. 5, fig. 7; Eocene, Europe.

Chiphragmalithus dubius (Deflandre). SULLIVAN, 1964, pl. 1, fig. 2; Paleocene, California. SULLIVAN, 1965, pl. 1, figs. 1-2; Eocene, California.

Zygolithus minutus PERCH-NIELSEN, 1967, pl. 5, figs. 6-7; Eocene, Denmark.

Zygolithus pediculatus PERCH-NIELSEN, 1967, pl. 5, figs. 8-11; Eocene, Denmark.

Neococcolithes dubius (Deflandre). RADOMSKI, 1968, pl. 48, fig. 17; Eocene, Poland. HODSON and WEST, 1970, pl. 2, fig. 1; Eocene, England. PERCH-NIELSEN, 1971b, pl. 42, fig. 10-12, 14-15; pl. 43, figs. 1, 3-5; Eocene, Denmark. BRATU and GHETA, 1972, pl. 4, fig. 48, Eocene, Czechoslovakia. SHERWOOD, 1974, pl. 8, fig. 6-7; pl. 11, fig. 20; Eocene, Texas.

Neococcolithes minutus (Perch-Nielsen). PERCH-NIELSEN, 1971b, pl. 42, figs. 1-4; Eocene, Denmark.

Neococcolithes pediculatus (Perch-Nielsen). PERCH-NIELSEN, 1971b, pl. 40, figs. 4-6; pl. 42, figs. 16-18; Eocene, Denmark.

Remarks: Z. dubius consists of a rim in the shape of an elongate ellipse with a delicate H-shaped crossbar. The rim is constructed of a single row of laths. These laths spiral around to form the rim and only their ends are visible in plan view.

Occurrence: Z. dubius occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

Family ZYGOSPHAERACEAE Braarud and Gaarder 1961

Genus DAKTYLETHRA Gartner 1969

Type species: *Daktylethra punctulata* Gartner

DAKTYLETHRA PUNCTULATA Gartner 1969

Plate 16, Figures 6-7

Daktylethra punctulata GARTNER *in* GARTNER and BUKRY, 1969, pl. 141, figs. 1-3; pl. 142, fig. 10; Eocene, Alabama. PERCH-NIELSEN, 1971b, pl. 58, figs. 1, 3-5; Eocene, Denmark. LOCKER, 1972, pl. 1, figs. 1-2; Eocene, Europe.

Calyptrolithus? morionum Deflandre. BALDI-BEKE, 1971, pl. 1, fig. 1; Eocene, Hungary.

Remarks: D. punctulata is a distinctive helmet-shaped holococcolith with a concave base and an elliptical cross section. The upper half of the helmet has numerous, large, circular pits and spike-like projections.

Occurrence: D. punctulata occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

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1, 4. *Discolithina multipora* (Kamptner) 206
1. Electron micrograph, X5,200 Distal view Sample B-30
4a. Cross-polarized light, X2,200 Sample B-28
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2. *Discolithina vesca* (Sullivan) Sample B-30 208
2a. Cross-polarized light, X2,200
2b. Phase contrast, X2,200

3. *Discolithina cribraria* Perch-Nielsen Sample B-15 206
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3b. Phase contrast, X2,200

5. *Discolithina* sp. A Sample B-30 210
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6. *Bramletteius serraculoides* Gartner Sample B-30 186
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7. *Cruciplacolithus staurion* (Bramlette and Sullivan) 195
7. Cross-polarized light, X2,200 Sample B-30

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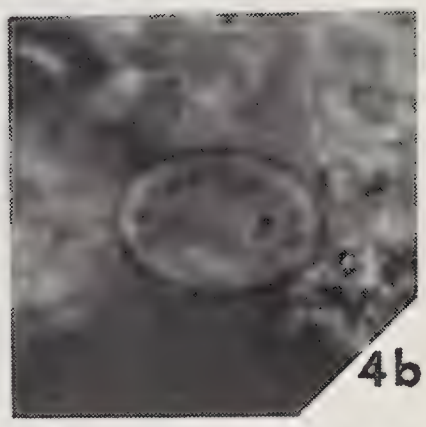
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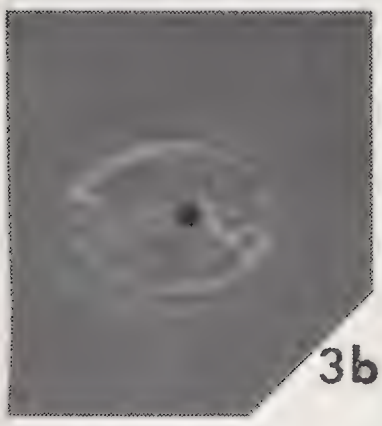
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PLATE 20

Genus HOLODISCOLITHUS
Roth 1970
Type species: *Discolithus macroporus* Deflandre

HOLODISCOLITHUS SOLIDUS
(Deflandre) 1954

Plate 22, Figure 5

Discolithus solidus DEFLANDRE *in*DEFLANDRE and FERT, 1954, pl. 12, figs. 14-16; Eocene, France. BRAMLETTE and SULLIVAN, 1961, pl. 3, figs. 14-15; Paleocene-Eocene, California; Eocene, Texas, France. SULLIVAN, 1965, pl. 4, fig. 8; Paleocene-Eocene, California.

Discolithus macroporus Deflandre. BÁLDI-BEKE, 1960, pl. 14, fig. 1; Oligocene, France.

Discolithina solida (Deflandre). LEVIN and JOERGER, 1967, pl. 2, fig. 7; Eocene-Oligocene, Alabama. BÁLDI-BEKE, 1971, pl. 1, fig. 7; Eocene, Hungary.

Holodiscolithus solidus (Deflandre). ROTH, 1970, pl. 11, fig. 5; Oligocene, Alabama, Blake Plateau, Trinidad.

Remarks: This elliptical discolith has six large, circular perforations on its surface. Normally there is one perforation at each end of the ellipse and two pores on each side of the longitudinal axis. Little Stave Creek specimens resemble those illustrated by Levin and Joerger (1967), in which one of the pores is somewhat off center. This species is constructed of several thin layers or crystals parallel to the base of the specimen. It may be a holococcolith. According to Roth (1970), the building blocks are cubes, but their shape is unclear in Little Stave Creek specimens. *H. solidus* is similar to *Holodiscolithus macroporus* (Deflandre) in structure, but has fewer perforations on its surface.

Occurrence: H. solidus occurs in the upper middle Eocene (Blow's P14) of Alabama.

Genus LANTERNITHUS
Stradner 1962
Type species: *Lanternithus minutus* Stradner

LANTERNITHUS MINUTUS
Stradner 1962b

Lanternithus minutus STRADNER, 1962a, no illustration; Eocene, Yugoslavia. STRADNER, 1962b, pl. 2, figs. 12-15; Eocene, Austria. STRADNER, 1964, text-figs. 17-18. LOCKER, 1967, text-figs. 1-3; pl. 1, figs. 1-8; Eocene, Germany. LOCKER, 1968, pl. 2, fig. 7; Eocene, Germany. RADOMSKI, 1968, pl. 46, figs. 24-28; Eocene, Poland. GARTNER and BUKRY, 1969, pl. 139, figs. 4-6; pl. 142, figs. 8-9; Eocene-Oligocene, Alabama. MARTINI, 1969b, pl. 2, figs. 24-25; Eocene-Oligocene, Switzerland. POZARYSKA and LOCKER,

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1-4. *Transversopontis obliquipons* (Deflandre) 220
1. Electron micrograph, X8,700 Distal view Sample B-30
2. Electron micrograph, X8,700 Prox. view Sample B-30
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6b. Phase contrast, X2,200
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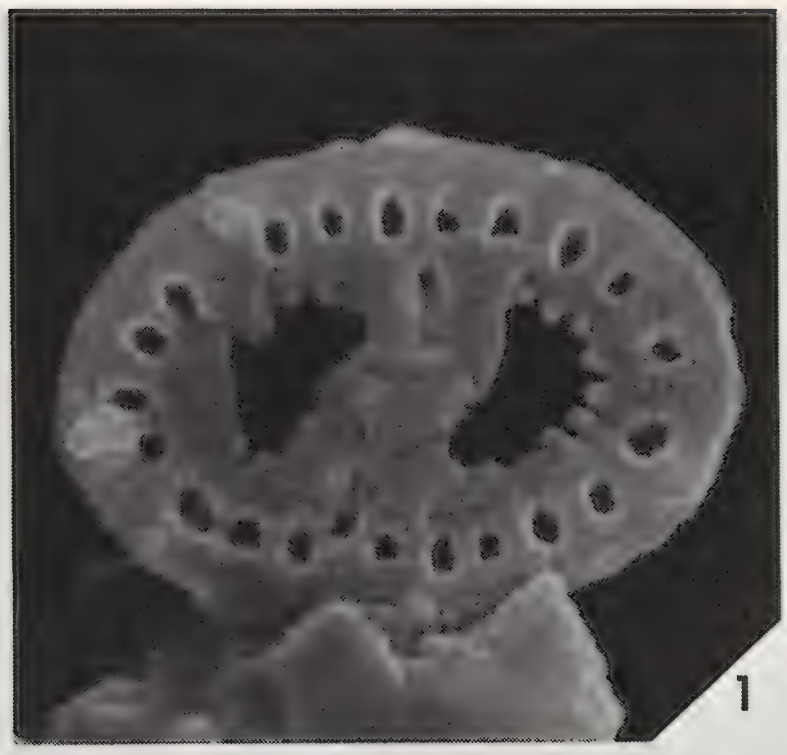
8. *Reticulofenestra callida* (Perch-Nielsen) Sample B-28 197
8a. Cross-polarized light, X2,200
8b. Phase contrast, X2,200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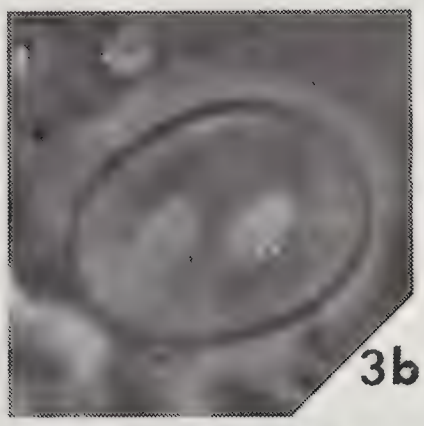
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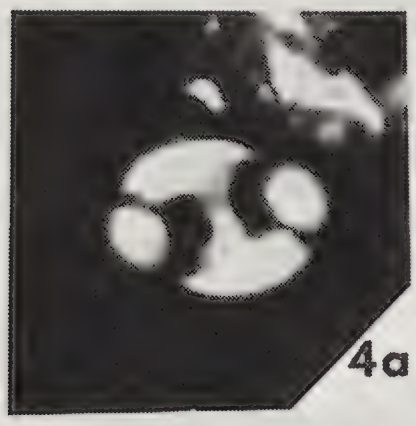
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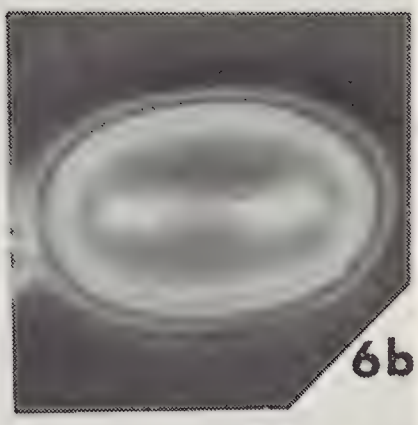
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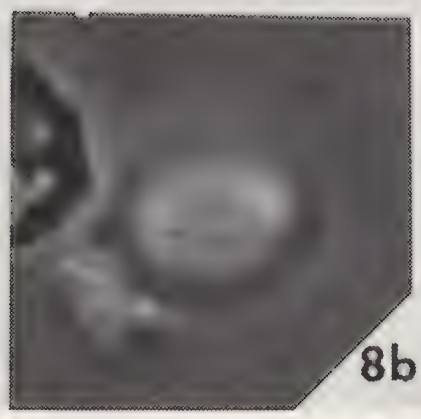
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PLATE 21

1971, pl. 2, fig. 30; Eocene, Poland. BRATU and GHETA, 1972, pl. 5, figs. 59, 62; Eocene, Czechoslovakia. LOCKER, 1972, pl. 12, fig. 8; Eocene, Europe.

Remarks: This elongate hexagonal holococcolith (formed of uniform-sized rhombs) has a multiple-layered base and six inward sloping sides, each side a trapezoid in shape. The top appears to have several large pits, which give this surface a hollowed-out appearance. *Lanternithus minutus* is similar to *L. duocavus* Locker, which is distinguished by two large, circular depressions on its upper surface.

Occurrence: L. minutus occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

Genus ORTHOZYGUS
Bramlette and Wilcoxon 1967
Type species: *Zygolithus aureus* Stradner

ORTHOZYGUS AUREUS
(Stradner) 1962b
Plate 13, Figure 3

Zygolithus aureus STRADNER, 1962b, pl. 1, figs. 31-36; Eocene, Holland. LEVIN, 1965, pl. 41, fig. 10; Eocene, Mississippi. STRADNER and ADAMIKER, 1966, pl. 3, fig. 2; Eocene. LEVIN and JOERGER, 1967, pl. 2, figs. 19-21; pl. 4, fig. 15; Eocene-Oligocene, Alabama.
Orthozygus aureus(Stradner). BRAMLETTE and WILCOXON, 1967, pl. 9, figs. 1-4; Oligocene, Trinidad; Eocene, Mississippi. GARTNER and BUKRY, 1969, pl. 139, figs. 1-3; pl. 142, figs. 5-6; Oligocene, Alabama. MARTINI, 1969b, pl. 2, fig. 21; Eocene-Oligocene, Switzerland. BALDI-BEKE, 1971, pl. 1, fig. 17; Eocene, Hungary. PERCH-NIELSEN, 1971b, pl. 59, figs. 11-12; Eocene, Denmark. LOCKER, 1972, pl. 5, figs. 9-10; Eocene, Europe.
Zygosphaera aurea (Stradner). STRADNER and EDWARDS, 1968, pl. 44, fig. 6; Eocene, New Zealand. BILGÜTAY, *et al.,* 1969, pl. 4, fig. 12; Eocene, France.

Remarks: O. aureus is a holococcolith with an elliptical distally flaring ring and a wide complex bridge across the short dimension of the ring. The bridge is dome-shaped with numerous, small, shallow and deep pores which are radially arranged at several levels around the dome. Near the top of the dome Little Stave Creek specimens have six pores in a circle. Specimens illustrated by Perch-Nielsen have a narrow bridge and a less well-developed circular dome.

Occurrence: O. aureus occurs in the upper middle Eocene (Blow's P14) of Alabama.

PLATE 22

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1, 3. *Transversopontis fimbriatus* (Bramlette and Sullivan) 220
1. Electron micrograph, X5,200 Sample B-30
3a. Cross-polarized light, X2,200
3b. Phase contrast, X2,200
2. *Discolithina wechesensis* Bukry and Percival Sample B-16 210
2a. Cross-polarized light, X2,200
2b. Phase contrast, X2,200
4. *Discolithina* sp. B Sample B-30 210
4a. Cross-polarized light, X2,200
4b. Phase contrast, X2,200
5. *Holodiscolithus solidus* (Deflandre) Sample B-30 240
5. Electron micrograph, X17,400
6. *Coccolithus crassipons* Bouché Sample B-15 194
6a. Cross-polarized light, X2,200
6b. Phase contrast, X2,200
7. *Coccolithus* sp. A Sample B-30 194
7a. Cross-polarized light, X2,200
7b. Phase contrast, X2,200

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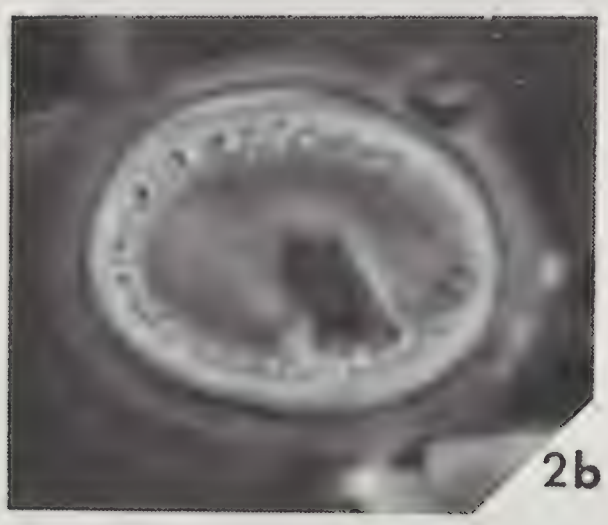
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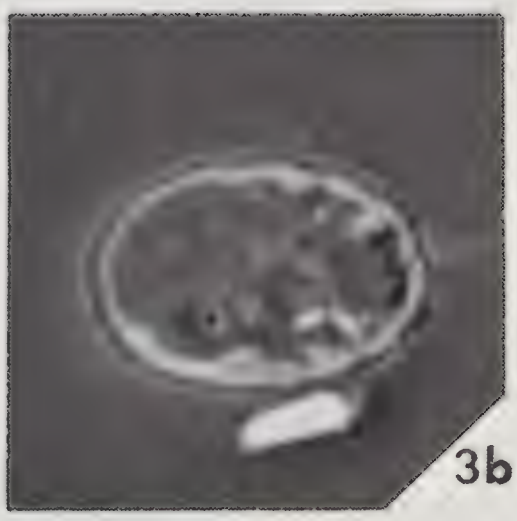
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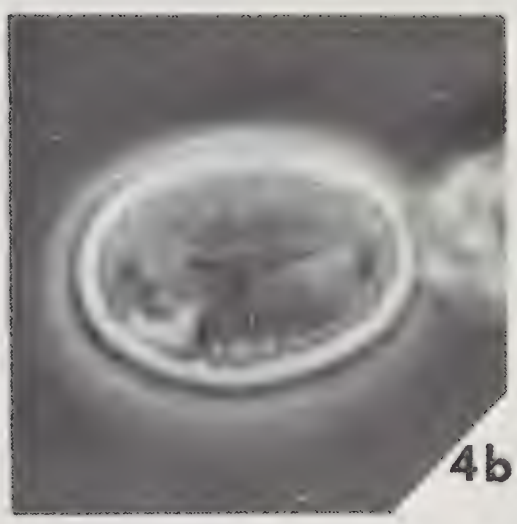
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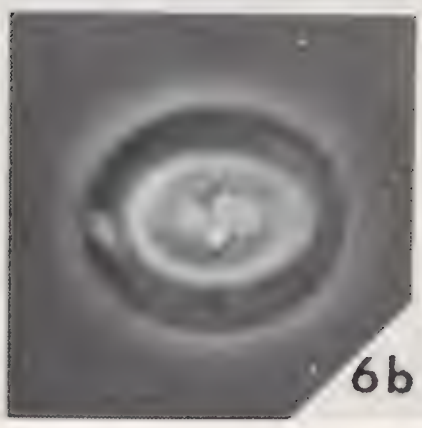
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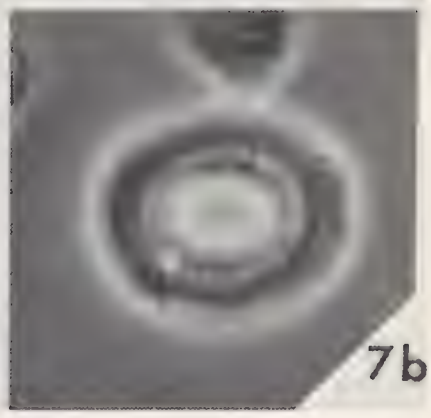
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PLATE 22

Genus ZYGRHABLITHUS
Deflandre 1959
Type species: *Zygolithus bijugatus* Deflandre

ZYGRHABLITHUS BIJUGATUS
(Deflandre) 1954
Plate 24

Zygolithus bijugatus DEFLANDRE *in* DEFLANDRE and FERT, 1954, pl. 11, figs. 20-21; text-fig. 59; Oligocene, New Zealand.

Rhabdolithus costatus Deflandre. DEFLANDRE and FERT, 1954, pl. 11, figs. 8-11; text-figs. 41-42; Oligocene, New Zealand.

Isthmolithus claviformis BRÖNNIMANN and STRADNER, 1960, text-figs. 25-43; Cuba.

Zygrhablithus bijugatus (Deflandre). BRAMLETTE and SULLIVAN, 1961, pl. 6, figs. 16-18; Eocene, California. BENEŠOVÁ and HANZLÍKOVÁ, 1962, pl. 2, fig. 16; Miocene, Czechoslovakia. BOUCHÉ, 1962, pl. 1, figs. 4, 9-11; Eocene, France. Not HAY and TOWE, 1962, pl. 2, fig. 2. SULLIVAN, 1964, pl. 7, figs. 9-10; Paleocene, California. LEVIN, 1965, pl. 42, fig. 1; Eocene, Mississippi. REINHARDT, 1966, pl. 21, fig. 12; Eocene, Germany. GARTNER and SMITH, 1967, pl. 8, figs. 1-6; Eocene, Louisiana. LEVIN and JOERGER, 1967, pl. 2, fig. 24; pl. 3, figs. 1-4; Eocene-Oligocene, Alabama. REINHARDT, 1967, pl. 4, figs. 21-22; pl. 7, fig. 5; Eocene, Germany. HAQ, 1968, pl. 7, fig. 10; pl. 9, figs. 10-11; Eocene, Germany. LOCKER, 1968, pl. 2, fig. 20; Eocene-Oligocene, Germany. RADOMSKI, 1968, pl. 43, figs. 11-13; Eocene, Oligocene, Poland. STRADNER and EDWARDS, 1968, pls. 42-43; Eocene-Oligocene, New Zealand. GARTNER and BUKRY, 1969, pl. 140, figs. 3-6; pl. 142, figs. 1-2. MARTINI, 1961b, pl. 2, figs. 19-20; Oligocene, Switzerland. HODSON and WEST, 1970, pl. 3, fig. 2; Eocene, England. HOFFMANN, 1970, pl. 1, fig. 2; pl. 6, figs. 1-8; Eocene, Germany. BALDI-BEKE, 1971, pl. 2, fig. 12; Eocene, Hungary. HAQ, 1971a, pl. 10, fig. 7; Eocene, Pakistan. HAQ, 1971b, pl. 12, fig. 5; pl. 13, figs. 11-14; pl. 17, fig. 8; Oligocene-Eocene, Germany. HAQ, 1971c, pl. 17, fig. 5; Oligocene, Syria. PERCH-NIELSEN, 1971b, pl. 58, figs. 7-9; pl. 59, fig. 10; Eocene, Denmark. POZARYSKA and LOCKER, 1971, pl. 2, figs. 7-8; Eocene, Poland. SHERWOOD, 1974, pl. 11, figs. 9-10; 13-14, 17-18; pl. 12, figs. 10-12; Eocene, Texas.

Rhabdosphaera semiformis BRAMLETTE and SULLIVAN, 1961, pl. 5, figs. 8-10; Eocene, California. SULLIVAN, 1964, pl. 7, fig. 7; Paleocene, California. SULLIVAN, 1965, pl. 7, fig. 3; Eocene, California. LEVIN and JOERGER, 1967, pl. 2, fig. 17; Eocene-Oligocene, Alabama.

Lucianorhabdus dispar STRADNER, 1961, figs. 49, 51-52; Eocene, Austria. STRADNER and PAPP, 1961, pl. 40, figs. 1-2, 6-11; Eocene, Austria. LEVIN and JOERGER, 1967, pl. 4, figs. 9-10; Eocene, Alabama.

Zygrhablithus sp. LEVIN, 1965, pl. 41, fig. 11; Eocene, Mississippi.

Sujkowskiella enigmatica HAY, MOHLER, and WADE, 1966, pl. 13, figs. 6-7; Eocene, USSR.

Zygrhablithus bijugatus crassus LOCKER, 1967, pl. 1, fig. 7; pl. 2, figs. 7-8; Eocene-Oligocene, Germany. LOCKER, 1972, pl. 3, fig. 16; Eocene, Europe.

Zygrhablithus bijugatus bijugatus (Deflandre). LOCKER, 1972, pl. 2, fig. 12; pl. 3, fig. 12; Paleocene, Europe.

Zygrhablithus cf. *Z. bijugatus* (Deflandre). PERCH-NIELSEN, 1972, pl. 15, figs. 6-7; Oligocene, Atlantic.

PLATE 23

Figures

1. *Sphenolithus radians* Deflandre Sample B-30 234
1. Electron micrograph, X10,400

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3. *Chiasmolithus grandis* (Bramlette and Riedel) Sample B-15 193
3a. Cross-polarized light, X2,200
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4. *Naninfula* sp. Sample B-30
4. Electron micrograph, X8,700

5. *Naninfula* sp. Sample B-30
5. Electron micrograph, X8,700

6. *Gongylis salzwedelensia* Hoffmann Sample B-30 246
6. Electron micrograph, X4,400

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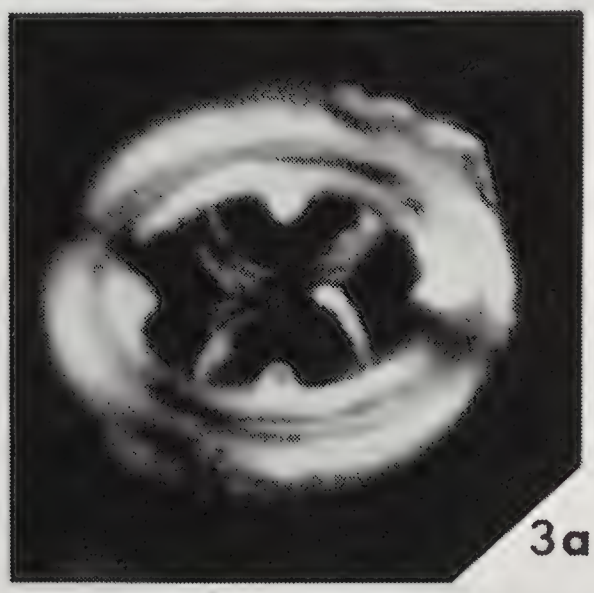
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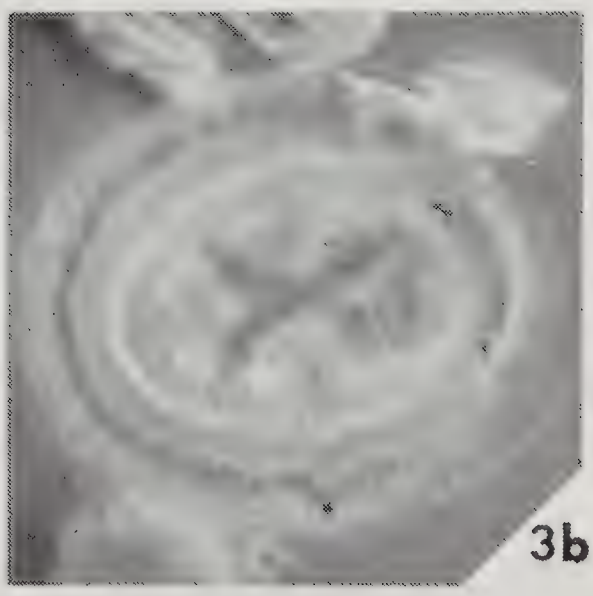
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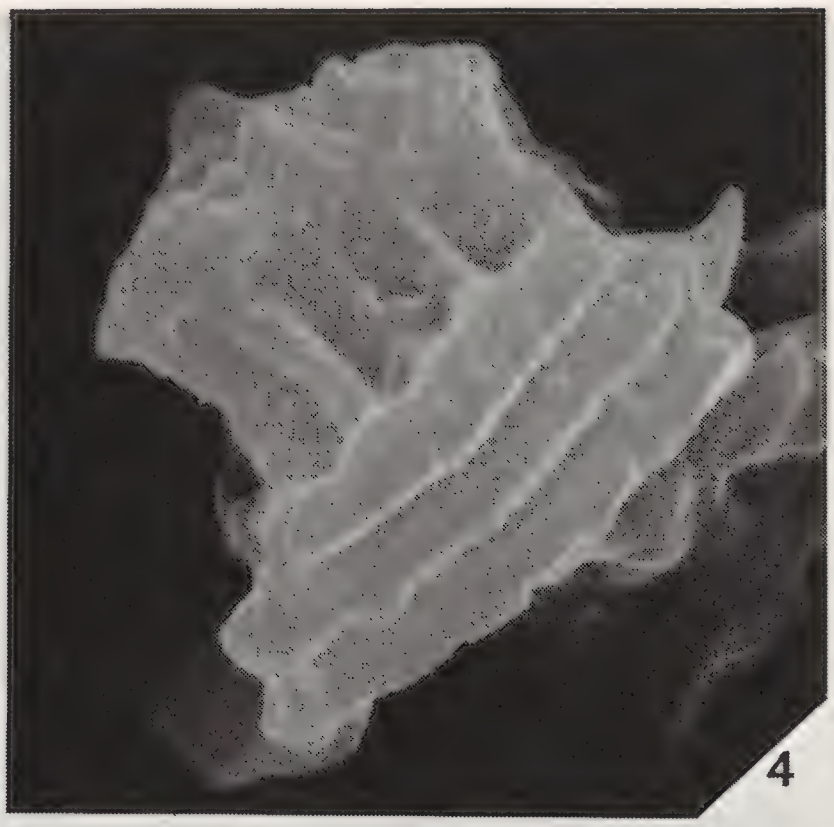
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PLATE 23

Remarks: This holococcolith has an upward flaring elliptical base, which is surmounted by a complex stem-like feature. This stem is X-shaped where it joins the basal disc. There is a circular depression in the base between each of the crossbars of the X. The crossbars rise upward as blade-like vanes to form the stem. In some specimens there is a small central knob on the top of the stem and lateral spines at the top of each blade. Other forms have very wide blades (Plate 24, Figure 5) and these were placed in a separate subspecies by Locker (1967). Specimens often break in half along the short axis of the base and these half specimens have been described under several different generic and specific names.

Occurrence: Z. bijugatus occurs throughout the middle Eocene (Blow's P11-P14) of Alabama.

Incertae sedis

Genus GONGYLIS
Hoffmann 1970
Type species: *Gongylis salzwedelensia* Hoffmann

GONGYLIS SALZWEDELENSIA
Hoffmann 1970

Plate 23, Figure 6

Gongylis salzwedelensia HOFFMANN, 1970, pl. 5, figs. 1-4; Eocene, German.

Remarks: This unusual, cone-shaped form has large irregular crystals, which form the base of the cone. Specimens from Little Stave Creek and Germany appear to be broken off from some other structure and this form may be unrelated to the coccolithophores.

Occurrence: G. salzwedelensia was only found in the upper middle Eocene (Blow's P14) of Alabama.

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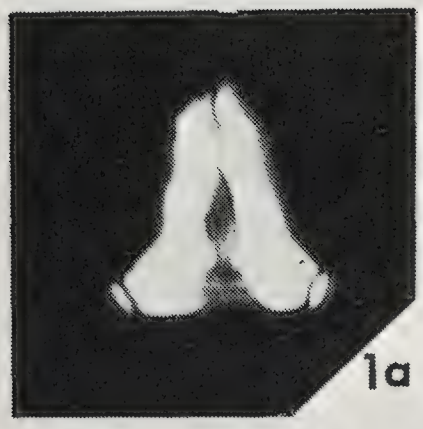
PLATE 24

Figures Page

1-7. *Zygrhablithus bijugatus* (Deflandre) 244
1a. Cross-polarized light, X2,200 Sample B-30
1b. Phase contrast, X2,200
2. Cross-polarized light, X2,200 Sample B-30
3. Electron micrograph, X8,400 Sample B-30
4a. Cross-polarized light, X2,200 Sample B-28
4b. Phase contrast, X2,200
5a. Cross-polarized light, X2,200 Sample B-15
5b. Phase contrast, X2,200
6. Electron micrograph, X10,400 Sample B-30
7a. Cross-polarized light, X2,200 Sample B-30
7b. Phase contrast, X2,200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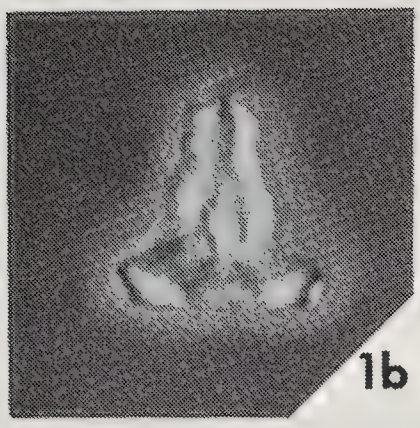
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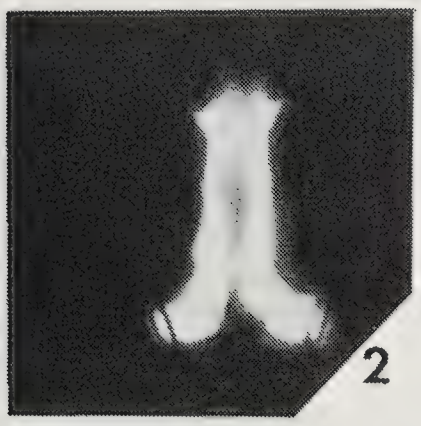
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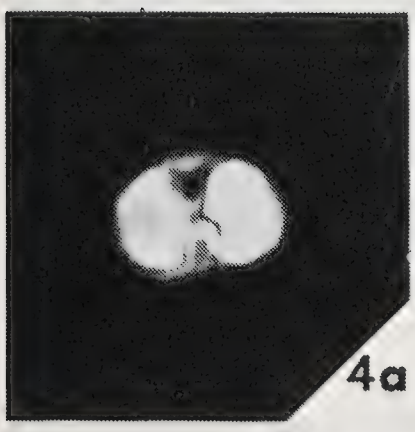
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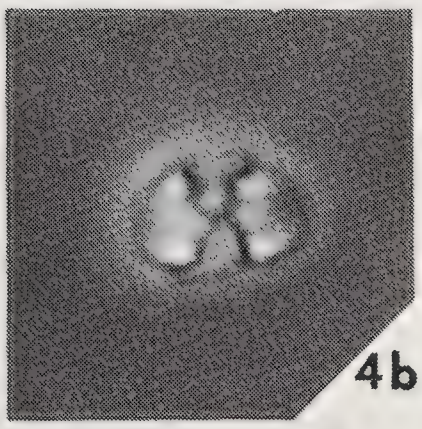
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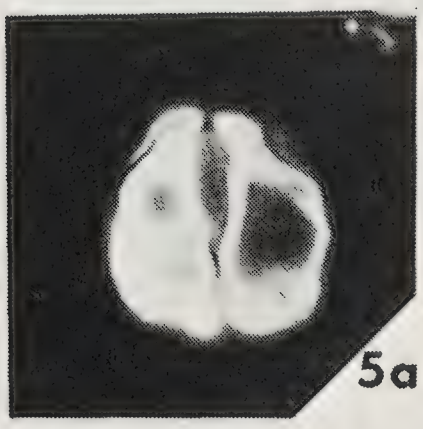
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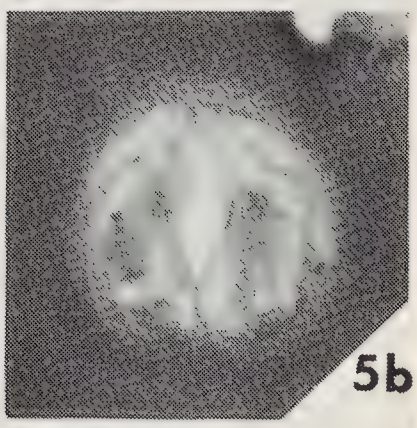
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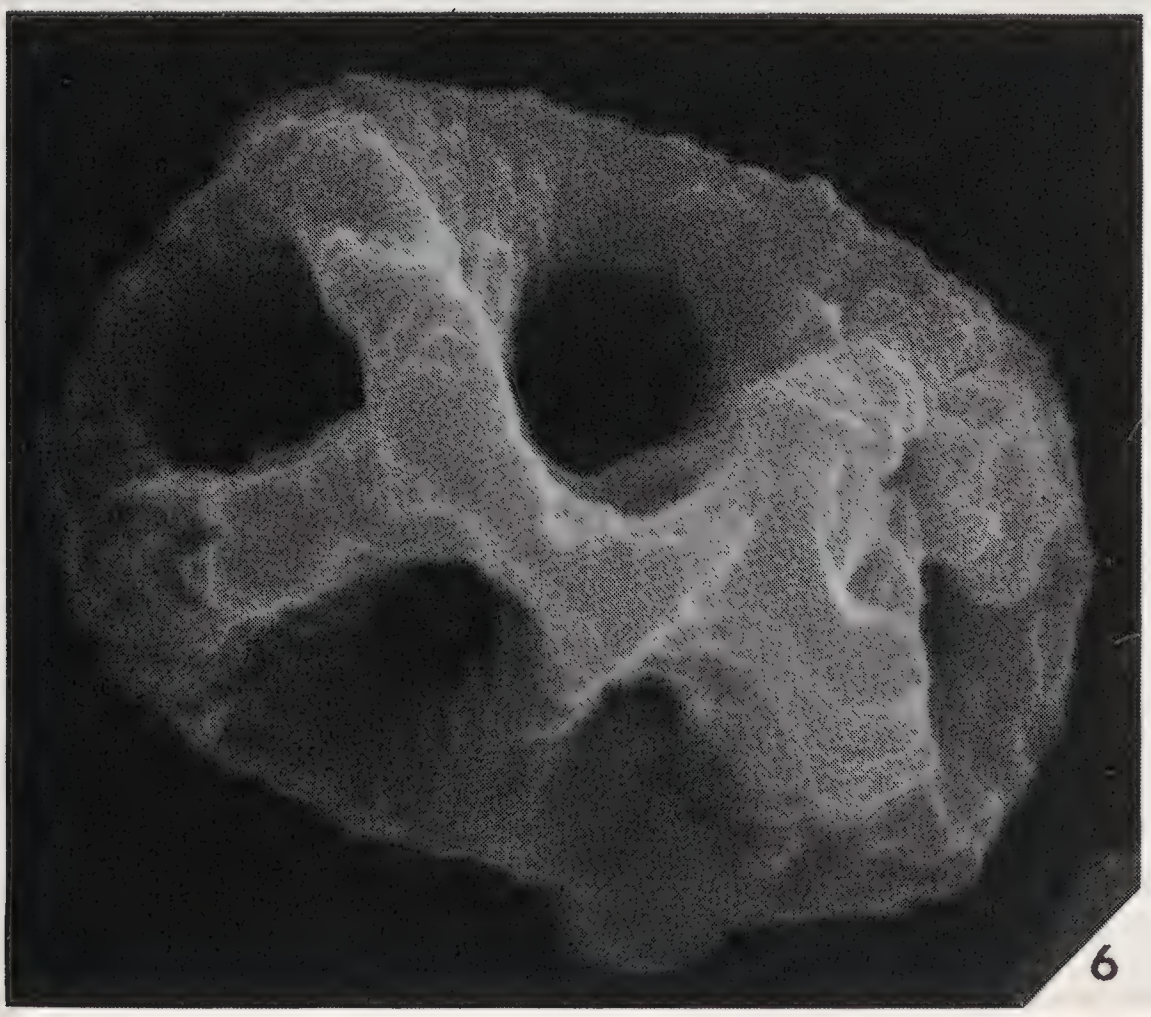
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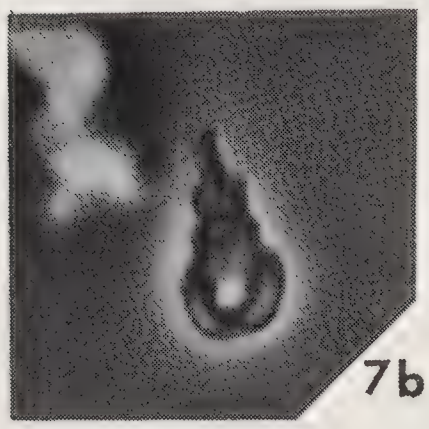
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PLATE 24

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A POPULATION STUDY OF THE BENTHONIC FORAMINIFERIDA IN NORTHERN BISCAYNE BAY, FLORIDA

BRIAN L. ANDERSEN
TULANE UNIVERSITY

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I. ABSTRACT

A portion of northern Biscayne Bay, Dade County, Florida, was investigated to determine the distribution of its benthonic foraminiferal assemblage. Percentages were calculated for the standing crop and total population from a count of all specimens present in aliquots of 26 samples taken from 15 stations. One hundred fifty-two species belonging to 75 genera and 35 families have been identified.

Although the primary interest is the description of the fauna and its distribution, additional information on depth, temperature, and bottom condition was obtained to facilitate discussion of ecologic factors as they pertain to the patterns of distribution. The area is a complex positive estuarine bay, with influx of fresh waters from the west (inland) side and open ocean waters mixing on the east. The presence of barriers, natural and man-made, further complicates the water circulation and water quality, in addi-

EDITORIAL COMMITTEE FOR THIS PAPER:

WILBURN H. AKERS, Chevron Oil Company, New Orleans, Louisiana

WAYNE D. BOCK, University of Miami, Miami, Florida

HUBERT C. SKINNER, Tulane University, New Orleans, Louisiana

tion to the effects of tides, weather, and hydrologic factors.

Areal distribution and abundance of certain species can be correlated with the grain-size distribution of the sediments. The distribution of specimens illustrates areas of mixing or foraminiferal assemblages and the association of certain faunal assemblages with particular environmental conditions. The presence of several species not known to South Florida waters are noted herein. The species recognized are recorded in the section on systematics.

II. INTRODUCTION

The waters of northern Biscayne Bay were chosen for study of their benthonic foraminiferal assemblage. It is an area of complex conditions, affected by temperature, salinity, vegetation, tides, and climate, as well as by additional factors such as barriers to currents. Man's effects include sewage pollution and dredging. It is an area sufficiently removed from tracts where benthonic faunal assemblages have already been adequately catalogued.

This area offered an excellent opportunity for study of a warm, shallow water fauna with its distribution partially dependent on the "blend" of quartz sand sediments and calcareous sediments. Many species can be associated with particular environmental conditions and sediment grain sizes. During the study, many species were noted for the first time that were not previously known to be in the South Florida area.

In all, 152 species from 75 genera and 35 families were noted. They were identified from the 26 samples taken from 15 stations. Stations 1 through 11 were visited on March 6, 1973, and these, with stations 12 through 15, were sampled on May 22, 1973. Data pertaining to depth, temperature, and bottom conditions also were obtained. This information was gathered to facilitate the discussion of species distributions with regard to environmental parameters. Coarse fraction and foraminiferal number have been calculated for each sample, and the percentage distribution determined for the standing crop and total population for each sample. The percentages are based on over 18,000 specimens that were counted; more than 12,000 of these were also "picked" and mounted on paleontological slides.

The number of species illustrated in this report was somewhat limited by restrictions in the funds and time available for the project and in access to scanning electron microscope facilities. Those species chosen for illustration include the more abundant and characteristic species encountered and several of the species not known previously to occur in South Florida waters.

Stubbs (1940) sampled seven stations from the vicinity of Biscayne Bay and investigated the Foraminiferida occurring in the area. He found that the families Miliolidae and Peneroplidae were predominant. Of the 63 species described, from 23 genera, *Archaias angulatus* was the most abundant.

Weiss (1948) was mainly concerned with the occurrence and seasonal fluctuations of sedentary marine organisms within Biscayne Bay. However, he also discussed the general circulation patterns within the area, and also noted that salinity and temperature variations correlated directly to the climate and seasonal temperature changes of the atmosphere.

Hela, *et al.* (1957), while investigating the effects of pollution in Biscayne Bay, studied the hydrography of the area. Circulation patterns were analyzed and tidal predominance was noted. Salinity and oxygen content variations within the bay were observed, and lower values for each were found to occur nearer the western margins of the bay.

Moore (1957) made an ecological study of the Foraminiferida in the northern Florida Keys and recognized four faunal provinces: Florida Bay, back-reef, reef, and fore-reef. The Florida Bay environment is characterized by varying abundances of Miliolidae, Peneroplidae, Nonionidae, and Rotaliidae, with an absence of the Amphisteginidae, Textulariidae, Lagenidae, and Buliminidae. The families Amphisteginidae and Buliminidae are present in the back-reef environment. Moore found that live specimens of species only in the family Miliolidae were present in the Florida Bay environment and that the fauna of this area was sorted by current and wave action.

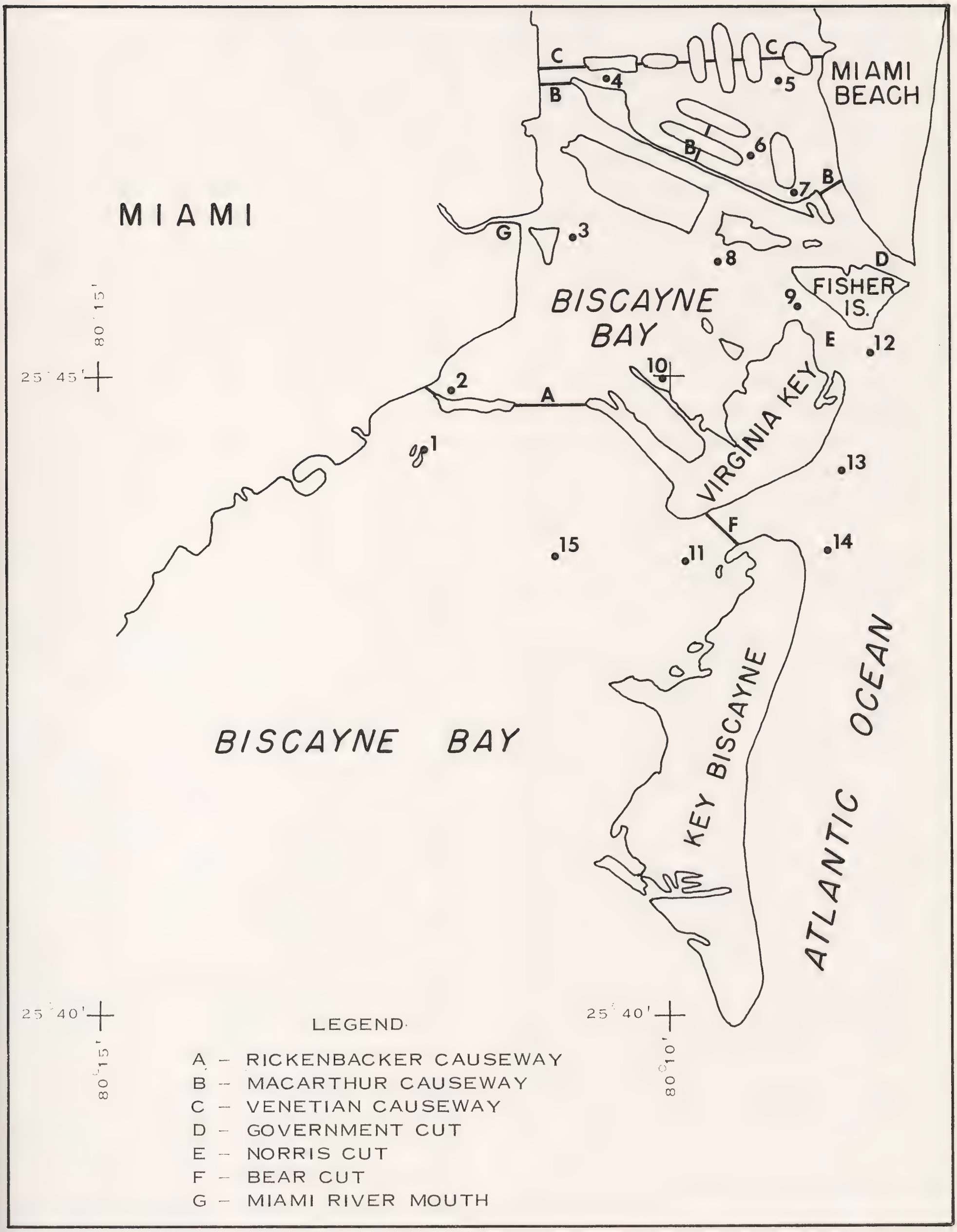

FIGURE 1. COLLECTING STATIONS

Bock (1961, 1967, 1971) has dealt extensively with the taxonomy and distribution of benthonic foraminiferal species in Florida Bay and adjacent waters. He has reported 99 genera and 235 species from South Florida waters and recognizes five general environments: the Straits and Gulf faunas (controlled by depth), the back-reef and bay faunas (controlled by temperature and salinity), and the brackish water fauna (controlled by salinity). In his first study, he discussed the distributional effects of current and wave sorting and the evidence that mixing of offshore and bay waters leads to a mixing of faunal assemblages. *Archaias angulatus, Quinqueloculina bosciana,* and *Q. poeyana* were the most common species recorded. In his second study, a "sediment" fauna and a *Thalassia testudinum* Konig fauna were recognized. Species of the second fauna generally are attached to turtle grass when alive.

Wanless (1967) made a thorough study of the distribution and deposition of sediments in Biscayne Bay. He discussed the existing circulation patterns and the hydrologic factors involved which are presently affecting the distribution of sediments.

Wright and Hay (1971, Bock, *et al.*) sampled along a traverse through a back-reef environment in the Florida Keys. Standing crop and total population of the benthonic foraminiferal community were studied and distribution was determined. The data collected reveal that greater numbers of live and dead foraminifers are associated with areas covered by vegetation, and that many specimens are directly attached to this vegetation (normally *Thalassia testudinum,* turtle grass).

III. GENERAL DESCRIPTION OF AREA

The area of northern Biscayne Bay chosen for study is irregular in shape and bounded by latitudes N25°47.3' on the north and N25°43.5' on the south, and longitudes of W80°12.2' on the west and W80°08.3' on the east. It is the central portion of the larger northern bay complex, and includes approximately ten square miles of water surface and six square miles of exposed land surface. Northern Biscayne Bay includes all basin waters contained within the Dade County metropolitan areas on the western mainland and a series of islands to the east. Miami Beach, Fisher Island, Virginia Key, and Key Biscayne represent the southern-most extension of the barrier sedimentary islands along the Atlantic coast, and these clastic sediments have been transported from the north and offshore by longshore currents (Wanless, 1967).

Government Cut was dredged to create a Main Ship Channel in 1905, and Fisher Island was a secondary result. The other two main channels into the area of study are Norris Cut between Fisher Island and Virginia Key, and Bear Cut, which separates Virginia Key and Key Biscayne.

At the turn of the century, northern Biscayne Bay was considered a shallow lagoon, and the unspoiled region had a great diversity of plant and animal life associating within the clear, warm waters. Man has been the greatest factor in changing the quality of the water and the circulation patterns controlling distribution factors of the remaining fauna. Dredging created boat channels and the spoil banks were used as a base for constructing residences and causeways. For many years the bay served as a depository for untreated sewage originating in the municipalities along the Miami River. This sewage influx has been brought under control but still some pollutants are getting into the bay waters from the businesses and residences in the area. No new sediments reach the area since all of the shoreline is lined with bulkheads or walled in.

The northern part of Biscayne Bay is now classified as a positive, shallow, tidal bar-built estuary (Hela, *et al.,* 1957). The circulation of the waters within and adjacent to the northern bay area has been studied along with its effect on various parameter distributions (salinity, oxygen content, sediment size and type) by several authors (Weiss, 1948, Hela, *et al.,* 1957, Wanless, 1967). The hydrography of the region will be discussed under the following topics:

1) *Tides*—Tides are semidiurnal but do not arrive at all bay stations at the same

time. At the Miami harbor entrance the mean tidal range is 0.8 meters, or about 2.6 feet. The range is less in the bay (Wanless, 1967). Winds affect the time and height of predicted tides.

2) *Tidal currents*—Southern Biscayne Bay receives warm oceanic waters of the Gulf Stream through numerous tidal channels along the eastern side of the bay. Tidal waters reach the area under study primarily through the Main Ship Channel, Norris Cut, and Bear Cut. Flow through these channels and under the bridges of the man-made islands has been measured (Hela, *et al.*, 1957).

3) *Tidal exchange*—Northern Biscayne Bay is too shallow for density stratification (Hela, *et al.*, 1957), so mixing of the incoming tidal flow with water in the bay is "confined to an interface along the perimeter of the incoming water" (Wanless, 1967, p. 9). Weiss (1948) had concluded earlier that little mixing occurred between the water of the north bay and the ocean during each tidal cycle. He noted that in some areas, however, strong currents developed between the closely spaced islands. This brought to certain sites an alternation of bay water and ocean water.

4) *Longshore currents*—Ocean swells resulting from the northeast trade winds arrive from the north, northeast, and east and set up southerly longshore currents (the agent that created the barrier island complex). The summer months also have smaller swells and waves from the south and southeast that cause northerly inshore currents (Morrill and Olson, 1955, *in* Wanless, 1967).

5) *Waves*—The entire bay is protected from offshore swells. Waves in the study area are predominantly wind-generated. Boat wakes will not be considered, although boat operation could be a factor in the distribution of foraminiferal tests in localized areas. In the summer, winds are gentle to moderate, and generally prevail from the southeast and east. Winter winds are stronger and arrive from the northeast and east. Wanless (1967) found that when the wind was less than 20 knots, waves within the bay were less than 0.7 meters high, with winter storm waves reaching one meter. Within the landlocked portion of the north bay, winds would cause slightly smaller waves due to the decreased fetch distance.

6) *Fresh water influx*—Weiss (1948) observed that the waters of the north bay were considerably affected by land and sewage drainage. Much of the fresh water introduced to the western boundary of the study area is from the Miami River, which originates in the Everglades swampland. Burlingame Island, at the river mouth, helps divert the fresh water to the north and south. Other small rivers and creeks are located farther north and south in the bay region. Miami is in the subtropical belt and normal yearly rainfall is over 125 centimeters. It is known that ground water percolating along western Biscayne Bay also mixes with the bay waters.

7) *Salinity*—Although the figures available are not recent, they are believed to be valid since the processes that affected salinity then are the same as the processes occurring now. The seasonal variation (lower salinity in summer, higher in winter) can be directly related to the amount of rainfall. More precipitation results in greater fresh water runoff and higher artesian flow of ground water. Weiss (1948) commented that salinity, which fluctuates much more in the northern bay waters than in the open ocean due to the seasonal variation in rainfall, helps indicate the isolation of this region from the open sea. Salinity fluctuations due to evaporation are related to the climate (temperature and rainfall), and daily fluctuations occur as salinity increases with the incoming tide. Bock (1967) also noted a direct relationship of salinity to depth. There is more water with increasing depth so less dilution can occur by fresh water runoff. The greater fresh water influx is on the western margin of Biscayne Bay. Mixing of bay and ocean waters is restricted to the eastern margin, although the greatest tidal salinity ranges exist near the middle of the study area. Data and figures (Hela, *et al.*, 1957) correspond with expectations. Average salinity values near the Miami River and western shores range from 20 to 25 parts per thousand, and the range on the eastern side of the bay is 30 to 35 parts per thousand. The western

waters are more brackish and near the main channels more oceanic water conditions exist.

8) *Temperature*—Seasonal variations correlate directly with seasonal air temperatures, as "the waters in the north bay respond quickly and directly to seasonal temperature changes of the air" (Weiss, 1948, p. 155). Temperature changes little with depth since Biscayne Bay is shallow throughout and vertical stratification is absent. Bottom water temperatures averaged 23 degrees centigrade on March 6, 1973, and 25 degrees on May 22, 1973. The air temperature range for the first half of 1973 was 32.8 degrees centigrade to 5.6 degrees centigrade.

9) *Circulation*—The mechanisms for circulation of the northern bay waters are not very complicated. Circulation is primarily tide driven, and the complete cycle occurs twice a day with the semidiurnal tide. There is also some wind driven drift of the surface waters. Because of the shallowness of the bay and lack of thermal and density stratification, the circulation system is one-layered (Hela, *et al.,* 1957). The path this system follows is more complex than the mechanisms driving it, however, due to the various channels and barriers present. Weiss (1948) noted that the MacArthur Causeway was a very effective barrier to water circulation since it was a continuous land-fill except for bridges at the eastern and western ends. The same observation applies to the Rickenbacker Causeway, built later to the south. Although not as continuous a land-fill as the other causeway, this one also restricts northward water flow from the southern to central portion of the study area. The two causeways have effectively divided the study area into three bodies supplied by ocean waters through the three main channels (Government Cut, Norris Cut, and Bear Cut). The other causeways have open bridges between the man-made islands and thus offer less resistance to circulation. The incoming tide waters move generally westward and, once inside the bay, are channeled northward (Hela, *et al.,* 1957). The river waters, being less saline and less dense, flow out over the top of the bay waters and proceed to mix because of the "stirring action" of the wind and waves within the bay area.

10) *Man's influence*—As already mentioned, dredging and land-fill influence sediment distribution and affect the circulation pattern. Bulkhead and seawall construction restricts deposition of new sediments since supplies are cut off. Man taps the rivers and ground water for various uses and affects the fresh water influx. Water quality varies in terms of oxygen, organic, and mineral content due to pollution outfall (including operation of water vehicles). This will be evident by inspecting lists of animals and plants that were once recorded within the bay and noting how many of these have disappeared (*The Miami Herald,* October 8, 1972).

11) *Hurricanes*—These are interesting storm phenomena of intense winds with high quantities of precipitation. The large amount of energy released is capable of causing storm tides greater than three meters above mean low water, and large driving waves are built up by the winds. These forces can have a significant effect on the sediment bottom of the shallow bay, transporting large quantities of sediment and ripping up the bottom vegetation. The greater precipitation would lower salinity in the bay, but this is partially offset by the greater tidal flow into the area. The South Florida area occasionally experiences a hurricane, but the last time the eye of a major hurricane passed close to the study area was 1966.

12) *Oxygen content*—The oxygen content of the bay waters will not be discussed at length except to state that levels are probably sufficient for bottom habitation by Foraminiferida in all areas with any water circulation. Pollution was at greater levels during previous studies (Hela, *et al.,* 1957), yet oxygen contents well above 40% had been found throughout the bay. The shallowness of the area and mixing by winds and tides allows all the bay waters to be sufficiently aerated.

The sediments within the study area are varied. Wanless (1967) studied these in great detail and much of this discussion is based on his findings. He made several coring traverses of Biscayne Bay and three of these cut through the area presently under study. The island complex is composed of long-

shore clastic sand that is predominantly medium to coarse, subrounded quartz and carbonate grains. Below the bay waters to the west these sands interfinger with the more angular quartz sands of the mainland. The mainland quartz sands, and much of the intrabay quartz sediment, have as their source the Pamlico Formation, a Pleistocene submarine bar now exposed along the mainland just north of Miami. On the eastern side of the bay are marine carbonate muds. Overlying much of the mud and sand is organic flock. Bedrock has been reached at depths between four and seven meters within Bear Cut and Norris Cut due to strong tidal currents, but seaward and bayward the channels digitate and shoals are present. Shoals continue below Cape Florida on Key Biscayne as a tidal bar belt and the amount of carbonate material present increases toward Soldier Key farther south. The shoals west of Norris Cut are principally muddy lagoon sands, and these become sandier towards the tidal channel. Due to the tidal currents, sediments within the channels are coarser. There is a greater abundance of shell material near the channels, also. The sediments within the bay area are mainly angular quartz grains that have been reexposed for distribution due to the extensive dredging in the area. The absence of material for deposition allows the organic flock to accumulate into considerable layers. The finer sediments are in areas of lower energy, which indicates wave and current sorting. Areas for these finer sediments include the bay side of Virginia Key and the residential island complex north of MacArthur Causeway and south of Venetian Causeway (which is taken as the effective northern limit of the study area).

The entire bay is considered as a shallow environment. However, there is appreciable variation in depth within the northern bay. The shallower areas are exposed at low tide, and some locations south of Rickenbacker Causeway are covered by about five meters of water at high tide. The Intracoastal Waterway was dredged to 2.4 meters below the mean low tide mark, and the Main Ship Channel is approximately nine meters deep. The shoal and channel system results in rapid depth change with little lateral movement. Depths observed during sampling are mentioned in the discussion on each station (see Table 1).

The amount of vegetation and larger animal activity on the bottom varied within the study area. Some areas, such as those emergent at low tide or swept by faster currents, were devoid of vegetation. The broad, flat-bladed sea grass known as "Turtle Grass" (*Thalassia testudinum* Konig) was the most common. In places, "Manatee Grass" is present, associated with turtle grass in the sparser areas. "Manatee Grass" (*Syringodium filiforme*) is a marine grass with narrow, cylindrical blades. Various species of green algae were also noted at isolated spots, usually nearer the shoal areas to the south. Small mounds in the sediments of the grassy areas and sandy patches testified to the presence of burrowing worms and crustaceans. Browsing mollusks are known to be present in some sections of the area, and echinoderms are rare.

Observations on bottom conditions and information obtained during sampling at each station have been arranged in table form and follow as Table 1, patterned after Stubbs (1940).

IV. PROCEDURES

All areas in the northern Biscayne Bay region chosen for study could be reached easily by the small outboard motor boat used to collect samples. Eleven stations were established for collection on March 6, 1973. Four stations were added during the sampling on May 22, 1973. The choice of stations was made in order that each would be significantly distant from the others and such that waters within and waters entering the bay would be well-sampled. Bearings were taken on landmarks to determine the latitude and longitude and to allow future reoccupation of each station for additional collecting.

In all, 26 samples were taken from the 15 stations selected. Each sample was hand-collected by skin-diving with mask and fins. The person taking the sample would drift a short distance from the boat and then dive

TABLE 1

Description of Stations

"A series" – March 6, 1973 collection "B series" – May 22, 1973 collection

Sample	Location	Depth	Temperature	Character
1A	N25°44.4' W80°12.2'	4 feet	24.0°C	Bottom hard, medium-coarse quartz sand, some mud, turtle grass vegetation, very near two small sand bar islands
1B	Above	5 feet	25.5°C	Medium amount of *Syringodium* ("pin" grass), thick turtle grass (*Thalassia*) vegetation, also much decaying vegetation over fine quartz sand, burrowers present, near two islands
2A	N25°44.8' W80°11.9'	7 feet	23.5°C	Medium quartz sand, some organic flock, light amount of *Syringodium* and *Thalassia,* station near western margin of bay
2B	Above	6.5 feet	25.0°C	Soft bottom, sediment with light amount of *Syringodium* cover, burrowers present, near Rickenbacker Causeway landfill on western bay margin
3A	N25°46.0' W80°10.9'	8 feet	22.0°C	Hard bottom, coarse quartz sand, some organic flock, small shell fragments, near Intracoastal Waterway dredge area, outside of mouth of Miami River
3B	Above	9 feet	25.0°C	"Pot-holed" algal mat with fine sand in slightly depressed areas, no vegetation, near dredge area, outside of mouth of Miami River
4A	N25°47.3' W80°10.6'	9 feet	22.0°C	Light amount of grasses, silty surface, some carbonate fragments, near northern limit of study area
4B	Above	8.5 feet	25.5°C	Soft sediment covering, vegetable matter decaying but no live grass, near northern limit of study area
5A	N25°47.3' W80°09.1'	12 feet	22.0°C	Light amount of grasses, silty surface, some carbonate fragments and organic flock, near northern limit of study
5B	Above	12 feet	24.5°C	Fine sand, no grass, small carbonate fragments, some organic flock, near northern limit of study area
6A	N25°46.7' W80°09.4'	11 feet	21.5°C	Soft bottom, very soft "mud-ooze", dark (high organic content), in area with restricted current movement
6B	Above	12 feet	24.5°C	Fine muddy sand, no grass, very soft bottom, decayed vegetable matter present, low amount of current movement
7A	N25°46.4' W80°09.0'	12 feet	23.0°C	Fine sand, much carbonate fragments, no live grasses visible, near Main Ship Channel currents
7B	Above	12 feet	24.0°C	Fine sand, no grass, decaying grass material with sediments, near Main Ship Channel currents
8A	N25°45.9' W80°09.6'	5 feet	22.0°C	Fine sand, some larger shell fragments, some decaying grasses present and turtle grass near, near a small shoal
8B	Above	4.5 feet	25.5°C	Coarse shelly quartz sand, small mollusks (to ½"), some turtle grass, very near a spoil bank and a small shoal
9A	N25°45.5' W80°08.9'	7 feet	23.5°C	Medium to coarse sand, mostly carbonates (shell and rock fragments), within Norris Cut, grasses on nearby shoals

9B	Above	5 feet	25.5°C	Sampled at edge of small shoal, turtle grass near, some bottom current, coarse, shelly, ½" mollusks present, within Norris Cut
10A	N25°44.9' W80°10.1'	4 feet	23.0°C	Three to six inches of fine sediments held by grasses, turtle grass predominating, much decaying matter, in protected area on bay side of Virginia Key
10B	Above	3 feet	25.5°C	Silt and algae covering on thick growth of *Thalassia* and *Syringodium,* three to six inch mat of silt and decaying grasses on bottom, in protected area on bay side of Virginia Key
11A	N25°43.5' W80°09.9'	4 feet	21.5°C	Very fine sand, some decaying turtle grass blades present, some carbonate material, on bay side of Bear Cut near shallow water shoals
11B	Above	5.5 feet	25.5°C	Medium growth of turtle grass and manatee grass, algae covering grass and bottom, fine sand, on bay side of Bear Cut near shallow water shoals
12B	N25°45.2' W80°08.3'	9 feet	24.5°C	Hard bottom, medium-coarse sand, predominately clastic shell, no grass, 2-3" bivalve shells present, ocean side of Norris Cut
13B	N25°44.2' W80°08.5'	9.5 feet	25.5°C	Hard bottom, no grass, coarse sand composed of clastic shell, slight bottom algae film, exposed to northern side sweep of currents through Bear Cut
14B	N25°43.6' W80°08.7'	8 feet	25.0°C	Medium sand of quartz and shell, some larger shell fragments, abundant turtle grass, some sand patches, exposed to southern side sweep of currents through Bear Cut
15B	N25°43.6' W80°11.0'	13 feet	24.5°C	Fine sand and silt, well burrowed, algal tufts, no grass, soft bottom, in open area of Biscayne Bay

to the bottom of an undisturbed area. At most stations the bottom was not visible from the surface and sampling proceeded randomly at whatever type of bottom was reached during the dive. Small jars were employed to skim off slowly the top one-half centimeter of bottom sediment over a small area. As observed during the sampling, this method does not disturb the sediments significantly. The cap was placed on the jar immediately after skimming the sediment surface to prevent loss of the sample. While positioned at each station, the temperature and depth readings were recorded, and bottom conditions were noted. Because of the small size of the boat, collecting was necessarily carried out on relatively calm days.

To prevent any deterioration of the cytoplasm of the organisms before staining could be accomplished, 90% denatured ethyl alcohol was added to each jar within four hours of the taking of each sample. Alcohol was used since formalin must be buffered to prevent the dissolution of calcareous tests due to the accidental formation of formic acid. The samples then could be safely stored to be processed later when more convenient.

In the laboratory, each sample was further prepared. This included staining of the cytoplasm to facilitate determination of the standing crop distribution and the splitting of each sample to smaller portions or aliquots.

Rose Bengal solution was the stain selected. Walton (1952) has discussed the feasibility of using Rose Bengal as a stain for cytoplasm and compared its effectiveness to other staining procedures. Rose Bengal stains

cytoplasm bright red, and Foraminiferida living when collected can be readily distinguished from dead ones. As suggested by Wright and Hay (1971), "living Foraminifers" will refer to those specimens that have taken the stain, and "dead Foraminifers" are all the unstained specimens. The stained samples were washed free of excess stain and then dried in an oven at temperatures below 80 degrees centigrade. The dried samples were then weighed (the stain has no appreciable weight), sieved on a #230 (63 microns or 4 phi) U.S. Standard Sieve and the greater than 63 microns portion weighed again. The weights obtained allowed calculation of the coarse fraction for each sample. For two reasons the cutoff point for sediment size was chosen at 63 microns rather than at 74 microns. Sedimentologists consider 63 microns as the minimum size of sand-sized particles. Also, it was noted while observing samples from areas nearby but outside the study area that juveniles and small tests are caught on the smaller mesh openings, and certainly these tests must be considered as part of the population. The sieved samples were then subdivided with a microsplitter. A sample size of 300 to 400 tests per sample was desired and aliquots were created until it was believed this level had been reached. No maximum number of splits was decided upon, as long as no bias was introduced in the makeup of each aliquot. Each chosen aliquot for the first 11 samples ("A series") was picked of every foraminifer. The individuals were identified and mounted, counts were made, and for each sample the percentage distribution for species was determined for the standing crop and total population. It soon was apparent that each of the first 11 samples had not been split far enough, and this was corrected for in splitting the 15 "B series" samples. The "B series" samples were split farther than the "A series" samples. In these more manageable aliquots (in terms of the number of individuals present), all benthonic foraminifers were identified and counted, and the distributions of standing crop and total population were determined.

Further work was carried out on the material. Each of the aliquots worked was weighed. The total number of Foraminiferida per gram, termed the foraminiferal number, was then computed. The values obtained can be used to compare the abundance of foraminifers in the different sampling areas, as well as comparison of these sample faunas with fossil faunal assemblages. Finally, the percentages derived from the counts of standing crop and total population in each sample have been grouped in Table 3 for easy comparison.

Preparation of specimens for viewing with the University of Miami's AMR Model 900 Scanning Electron Microscope was relatively simple. The specimens were attached to stubs by "double-stick" Scotch tape, and a gold-palladium alloy coating was applied. The film used for the original prints was Polaroid PN/55, black and white.

V. DISTRIBUTION

Much of the recent work on benthonic Foraminiferida has gone beyond the simple listing of species occurring in an area to discussion of possible effects of ecologic parameters on the distribution and frequency of these forms. The distribution and frequency in the Biscayne Bay area will be discussed in relation to the factors affecting the species identified from the samples collected.

A number of factors are known to have definite effects on the distribution and frequency of Foraminiferida. Some of these are: depth, temperature, salinity, oxygen content, wave and current sorting, sediment size and type, bottom vegetation, and pollution. Typically, the interrelationship of these factors prevents complete determination of the contribution of each factor, if any, to the distribution observed. Due to the various environmental factors, species are not uniformly distributed over the bottom, and Shifflett (1961) mentions two assumptions of which one should be wary. The first is the assumption that a total population recovered from a sample is representative of the living population at that sample locality. The second assumption frequently made is that a sample of a small cross-sectional area is representative of a large area on the sea floor. These assumptions are invalid because

of relict faunas, wave and current sorting, and the frequent faunal variation over short lateral distances. Wright and Hay (1971) concluded that closely spaced multiple samples are necessary for quantitative description of foraminiferal populations, but that widely spaced single samples are sufficient for characterizing what species are present in an environment. An additional consideration is that different conditions exist at a station at different periods of time, especially in shallow waters. All of this indicates that a very large number of samples is necessary to make an accurate study of effects on population and distribution due to the environmental factors.

In the present study, 11 stations were visited on March 6, 1973, and these with four additional stations were sampled on May 22, 1973. These 26 samples cannot be considered closely spaced, and there was little change in water conditions during the period between the sampling dates. The sampling is considered sufficient for determining the species present in the general environment. However, discussion of the distribution in terms of the previously mentioned factors will be restricted to that of the distributional variation among the stations. Any discussion of the changes through time in population distribution at a particular station has to be omitted because no station was repeatedly sampled during appreciably changing water conditions.

Depth and bottom water temperature were measured at each sampling site. The differences in depth among the stations is not appreciable, and depth was found to have little importance within this shallow bay in terms of distributional effects, other than the secondary aspect of the shallower areas being more susceptible to current and wave sorting. The temperature variation was not more than four degrees centigrade between any two stations, and cannot be considered a significant factor affecting distribution among the stations within the study area.

Salinity variation within the bay has been discussed elsewhere. The presence or absence of three particular species reflects especially well the salinity increase away from the western bay margin. *Ammonia beccarii parkinsoniana, Ammonia beccarii tepida,* and *Elphidium gunteri galvestonense* are reliable indicators of a stress environment. More accurately, the presence of only the two *Ammonia beccarii* subspecies would indicate stress conditions, with the additional presence of *Elphidium gunteri galvestonense* in large numbers indicating that the water is brackish and not hypersaline (Bock, 1973, personal communication). These species are found in high concentrations at stations 1, 2, 3, and 4, the ones nearer the western bay margin and affected by the greatest amounts of fresh water influx. Stations 5, 6, 7, 8, 10, and 15 have appreciable numbers of these species and reflect general bay salinity (Hela, *et al.*, 1957). The remaining stations have lower concentrations of these brackish water species and the water salinities are more nearly those recorded for open oceanic waters. This relationship between the mentioned species and salinity is perhaps the easiest to recognize, due to the large numbers of specimens present.

It will be difficult to discuss accurately the effects of oxygen content and pollution on the populations. Even during times of heavy pollution, it appears that the waters have been amply oxygenated (Hela, *et al.*, 1957). So, it will be assumed that oxygen content has had no recent effect on distribution within the bay area. The present benthonic fauna is not as varied as the one that existed at the turn of the century, and there is reason to believe that losses have also occurred in the foraminiferal assemblage. Limited data prevent one from stating specifically in what ways losses have occurred.

One of man's greatest effects on the distribution of benthonic Foraminiferida is dredging. This process stirs up silt that can cover and smother the bottom fauna. Dredging uncovers older sediments and the relict fauna may be reworked into the present fauna. Additionally, creation of islands and various channels leads to new water current routes which cause older sediments with their fauna to be redistributed. The location and extent of the marine grasses change, and it will be discussed later how distribution of

benthonic Foraminiferida closely ties in with distribution of bottom vegetation.

There are several observable correlations that can be made concerning the foraminiferal distribution and sediment size. Wave and current sorting is a very active process within the bay. The tests are sorted by size just as the sediments are, and observation of the samples show this indeed to be true. There are two other associations between the finer sediment sizes and species distribution, but coarse fraction values must be discussed first. Grain size distribution information from a coarse fraction determination is not as accurate as that which would be gained from a proper sieve analysis. The small amounts of obtained sample prevented sieve analysis; however, the coarse fraction determination actually is a sieve analysis, with only one sieve. The coarse fractions measured indicate the percentage of sample in grain sizes larger than 63 microns, but indicates nothing about grain size distribution within the coarse or fine fraction. Observation of the sample under the microscope, however, shows a marked tendency of the samples of higher coarse fraction to be coarser-grained also. Station 6 has the lowest coarse fraction and easily is the finest-grained; many of the greater than 63 micron sized sediments were really reworked faecal aggregates of smaller particles. This discussion will now proceed under the premise that in this area there is a direct relationship between coarse fraction and grain size, where coarser-grained samples generally are those with higher coarse fraction values. The other two relationships between sediment size and distribution, using calculated coarse fraction values, can be observed in Table 2. The trend is for the foraminiferal number, the number of Foraminiferida per gram of sample, to be larger for the samples with lower coarse fraction values (greater amounts of fine material). The other relationship is that there is generally an increasing number of species in the samples of increasing mud content (decreasing coarse fraction values). A notable exception to both relationships above is sample "7A", but additional factors here are the specimens associated with inshore transport and the more thorough selective sorting; both are strong factors because of station 7's favorable position with respect to these tidal current effects. These relationships seem to be generally correct, however, and evidence supporting them is their relationship to grassy flats. Many Foraminiferida live on the marine grass blades but are displaced when they die or the test is vacated. The grass traps finer sediments or tests, and the larger tests and sediments will be found in the coarser sand patches devoid of grass. The grass flat with the fine sediments will have the greater variety and greater number of specimens (Bock, 1967, Wright and Hay, 1971). A fourth relationship between grain size and foraminiferal distribution is the restriction of several agglutinated species to areas of finer sediments. Apparently, *Ammotium salsum, Pseudobolivina walshi,* and *Reophax nana* are dependent on these finer grains as building material.

An association is also observed between sediment type and distribution. Soritidae appear in greater abundance at stations more abundant in calcareous sediments. The channels have coarser calcareous sediments than occur elsewhere, transported inshore by tidal currents, and the association of large Soritidae tests with them indicates they are also associated offshore. Additional evidence for this relationship is the higher percentages of Soritidae in samples from southern Biscayne Bay, where the sediments are also more calcareous. As is the case in every distribution discussed here, the interrelationship of effects due to other factors, as well as the limited number of samples, prevents any definite analysis of to exactly what degree distribution and frequency of Foraminiferida is a reflection of the sediment properties.

Bock (1967) observed two other factors that affect foraminiferal distribution and abundance, but they will be only mentioned here since the data are not sufficient for evaluating their effects in Biscayne Bay. Bock noted several abundance relationships between species, and interpreted this as interspecific competition for survival under the conditions present at the time. In addition, he observed that this competition

among the foraminifers was apparently limited to species falling within the same general size range. The other factor is the number of other organisms in the area. Some animal forms may purposely feed on foraminifers, but other foraminifers are destroyed by the indiscriminate grazing of gastropods and other organisms. Abundance or absence of microscopic forms (and other nutrients) that serve as food for the Foraminiferida would also affect distribution and abundance.

Comments on the effects of vegetation on distribution will be included within the discussion on standing crop distribution. Bock (1967) investigated the relation between the two and observed that many species prefer living attached to marine grasses, especially *Thalassia testudinum* Konig. In addition to this control on the standing crop, he concluded that the distribution of turtle grass also controls the type of substrate present at a given locality, the substrate in turn controlling the distribution of the foraminiferal fauna. Other than noting this apparent relationship between vegetation and distribution, there is little information available on the effects of vegetation. Several of the stations were devoid of grass; no grass samples were taken; and, because of the condition of the water, over much of the bay it could not even be ascertained from the surface where the grasses were. Discussion on the standing crop will continue, however. Lynts (Bock, *et al.*, 1971) makes two points on variations between the standing crop of two samplings at a station; first, it is not possible to reoccupy the station position exactly, and second, there is variation of the environmental factors between the two times of the year. These points are valid, and changing conditions and variation over short lateral distances should be kept in mind. Wright and Hay (1971) feel that living populations must be examined in order to draw ecological conclusions. The problem is that:

> . . . live specimens could not be found of many genera and species that are abundant in the sediment samples from Florida Bay. Either the sampling and staining techniques are not correct or the tests in the sediment do not reflect the live Foraminifera in the area. Many more samples must be studied before the distribution of live Foraminifera in the area can be discussed with certainty. (Moore, 1957, p. 732)

Already handicapped by a lack of abundant samples, this discussion of the standing crop in relation to the various ecologic parameters is also handicapped by Moore's problem—the lack of live specimens. Less than 6% of the total number of specimens observed were alive (*i.e.*, took the stain). This is an indicator in itself, however. Phleger (1960) said that a low live to dead ratio indicates a low rate of sedimentation, and this the northern bay has. For example, though, there are only four live specimens occurring among the more than 1200 *Elphidium gunteri galvestonense* counted. Finding no live Soritidae in the bay does allow an ecologic conclusion to be made, contrary to Wright and Hay. By taking also into account their distribution and frequency, it can be assumed the Soritidae normally occur in more oceanic saline areas of predominantly carbonate sediments (as now exist to the east and south of the study area). In total, 50 species belonging to 32 genera and 21 families are observed living in the study area. Live specimens are most abundant in the brackish water and bay environments, and are most numerous at station one. This points toward the observation (Bock, 1967, Wright and Hay, 1971) that grasses are very important to many Foraminiferida, since this station has the best vegetative growth as evaluated on abundance and plant color. *Ammonia beccarii tepida* is the most abundant species in the standing crop, followed in total numbers by *Triloculina trigonula, Quinqueloculina bosciana, Ammonia beccarii parkinsoniana, Miliammina fusca,* and *Cribroelphidium poeyanum.*

The remaining discussion on distribution concerns the total population. Table 3 should be consulted.

Several families predominated within the study area. It should be kept in mind, however, that species and family abundances are dependent on the selected sampling sites and the amount of sample examined. If more samples had been examined from near the open ocean, more peneroplids would have been counted and the percentages would

TABLE 2

Sample number	Coarse fraction	Number of species found	Foraminiferal number
1A	92.5%	44	131
1B	96.3%	39	310
2A	96.7%	35	286
2B	92.8%	35	698
3A	96.8%	42	91
3B	94.1%	32	545
4A	29.9%	52	5,232
4B	45.3%	52	12,605
5A	89.0%	71	6,324
5B	90.8%	44	1,486
6A	6.9%	94	20,800
6B	22.7%	76	15,286
7A	99.3%	100	851
7B	78.6%	67	4,667
8A	91.7%	87	3,719
8B	97.9%	61	509
9A	88.1%	75	565
9B	95.6%	58	787
10A	49.3%	58	4,428
10B	58.1%	52	4,387
11A	67.4%	88	3,441
11B	78.6%	71	5,037
12B	98.2%	54	741
13B	98.7%	45	76
14B	93.8%	59	524
15B	50.0%	67	10,545

indicate a greater abundance of the family Soritidae; more brackish water stations would have increased the Rotaliidae counted. Additionally, the particular specimens of a large enough sample count from brackish waters, for example, could outnumber other specimens added together from two or even three smaller-sized samples collected in a more saline area. Statements made about the bay distribution in general, then, would be less valid than statements made for distribution among stations of comparable conditions, and even less valid than statements of distribution at a particular station or within a particular sample. Statements concerning distribution and abundance at several levels will be made, with confidence in the statements increasing with each level.

The first level is the general bay area under study. The total fauna is comprised of 152 species belonging to 35 families and 75 genera. Of the specimens examined, the families Rotaliidae, Miliolidae, Elphidiidae, and Soritidae are the most prevalent, in decreasing order of abundance. The *Ammonia beccarii* subspecies are by far the most abundant foraminifers and account for all but one specimen of the Rotaliidae reported. *Elphidium* and *Cribroelphidium* account for all of the Elphidiidae, and the Soritidae are mostly *Peneroplis* and *Archaias* specimens. Several Miliolidae genera are present in the bay but the most common ones are *Quinqueloculina, Triloculina,* or *Miliolinella.*

The next level of disucssion is on the three faunal zones that can be conveniently distinguished. They are the brackish water fauna, the bay fauna, and the eastern margin inshore transport fauna. Each will be discussed separately.

1) *Brackish water fauna*—This encompasses stations 1, 2, 3, and 4, and is easily discerned by the high percentages present of *Elphidium gunteri galvestonense* and the subspecies of *Ammonia beccarii.* All four stations are near the bay's western margin, an area of high fresh water influx; and salinity appears to be the prime factor controlling distribution with lesser effects of wave and current sorting. Families represented in decreasing order of abundance are

Rotaliidae, Elphidiidae, Miliolidae, and Bolivinitidae.

2) *Bay fauna*—Stations 5, 6, 7, 8, 10, and 15 are considered to contain considerable elements of the bay fauna. Salinity, dredging, bay and ocean water mixing, and wave and current sorting are all deemed important as distribution factors. Grasses and areas of finer sediments are associated with this fauna. In general, the greatest diversity of specimens occurs at these stations. Over two-thirds of the observed species occur at stations 6 and 7. The Miliolidae have become the most numerous, followed by the families Elphidiidae and Rotaliidae. Becoming more noticeable are the Discorbidae, Bolivinitidae, Caucasinidae, and Soritidae. Some of the more abundant specimens include: subspecies of *Ammonia beccarii, Asterigerina carinata, Bolivina lanceolata, Bolivina paula, Cibicides floridana, Cribroelphidium poeyanum, Discorbis mira, Elphidium advenum, Elphidium gunteri galvestonense, Fissurina* cf. *F. lucida, Fursenkoina compressa, Hanzawaia strattoni, Hauerina bradyi, Miliammina fusca, Miliolinella circularis, Peneroplis carinatus, Quinqueloculina bosciana, Q. lamarckiana, Q. poeyana, Q. polygona, Rosalina candeiana, Rosalina floridana,* and *Triloculina trigonula.*

3) *Eastern margin inshore transport fauna*—Stations 9, 11, 12, 13, and 14 are considered to contain the inshore transport fauna. Each of the stations is near the eastern edge of the study area. They are near or within a major tidal channel and so receive the greatest effects of the tidal current (Hela, *et al.*, 1957). Salinity conditions are more nearly like that of the open ocean environment. Considered as distributive factors would be the increased salinity and the wave and current sorting. Inshore transport, though, greatly affects the distribution and abundance of species in this area. The families, in order of decreasing abundance of specimens, are Miliolidae, Soritidae, Discorbidae, Elphidiidae, and Asterigerinidae. Also well evident are members of the Cibicididae, Amphisteginidae, and Bolivinitidae. Several species expected to be found in deeper ocean waters are present in or bayward of the channel areas. Some of these include: *Articulina antillarum, Asterigerina carinata, Astrononion stelligerum, Bigenerina irregularis, Bolivina goesii, Guttulina australis, Hauerina speciosa, Heterostegina depressa, Lagena striata, Loxostomum* spp., *Pseudonodosaria torrida, Pyrgo comata, Rectobolivina advena,* and *Trifarina bella.* There are also several species, notably *Peneroplis carinatus, Archaias angulatus,* and *Textularia agglutinans,* that appear to have been transported inshore from the outlying grassy areas. Evidence for the wave and current sorting includes many smaller specimens of the above occurring in the finer sediments of the bay area, but very few being carried completely to the western bay margin since tidal currents become decreasingly evident in that direction. The sediments found within the channel areas are coarser shell and carbonate fragments, and are further evidence of inshore transport since the barrier island complex is dominantly quartz sand.

Finally, the distribution observed at each station will be considered. The percentages computed in Table 3 are accurate for the distribution within that sample. More samples would be necessary, though, before analysis of the change of distribution through time while different conditions are occurring at each station site could be accomplished. Very probably the changes would be more significant in the standing crop, since this is more quickly affected by many of the environmental factors. The general trend was to find fewer species in the "B series" of samples than in the "A series". This seems due in part to less material being examined and less specimens counted. In addition, the exact sampling site could not be reoccupied. It will not be possible to correlate any changes in the observed fauna at each station to particular environmental factors.

The distribution and abundance of specimens for each station will be discussed individually. All samples from March 6, 1973, will be referred to by an "A", and those from May 22, 1973, will be designated by a "B". The "B" samples were gathered to allow a check on the "A" samples, and also to facilitate a more accurate discussion of the fauna present at the perimeter of the

study area. Information for each station can be found in Tables 1, 2, and 3.

Station 1—This station has a brackish water fauna. The Rotaliidae are the most important, and the Miliolidae and Elphidiidae follow. Minor families present include Rzehakinidae, represented only by *Miliammina fusca,* and Bolivinitidae. The most abundant species are two subspecies of *Ammonia beccarii,* followed by *Triloculina trigonula, Cribroelphidium poeyanum, Quinqueloculina poeyana, Miliammina fusca, Elphidium gunteri galvestonense,* and *Quinqueloculina bosciana.* The only specimen of *Massilina secans* observed was found here. In total, 53 species occur at station 1, 44 in the "A" sample and 39 in the "B" sample. This greater abundance of species in the "A" sample generally occurs at every station, and is discussed earlier.

Station 2—This station is also considered to be in brackish water. The *Ammonia beccarii* subspp. account for over half the specimens in the "A" and "B" samples, so again Rotaliidae is the predominant family. The Elphidiidae, Miliolidae, and Bolivinitidae are the other families of importance, and *Elphidium gunteri galvestonense* and *Cribroelphidium poeyanum* are the next most common species. There are 48 species at station 2, 35 species in each sample.

Station 3—Station 3 is definitely brackish water; just on the other side of a small island from the mouth of the Miami River. Fifty-one species occur at this station, 42 "A" species and 32 "B" species being identified. The Rotaliidae family again accounts for over 50% of the total population, and all are *Ammonia beccarii.* The Elphidiidae are second-most common followed by the Miliolidae. *Cribroelphidium poeyanum, Elphidium gunteri galvestonense,* and *Triloculina trigonula* are other very common species.

Station 4—This station has finer sediments than the other three brackish water stations. This may be due to current sorting, since the specimens are smaller; but, the percentages of species closely align with the other brackish water samples. The Rotaliidae are the most numerous, and following in abundance are the Elphidiidae, Miliolidae, and Bolivinitidae. *Ammonia beccarii* is the most common, followed by *Cribroelphidium poeyanum, Elphidium gunteri galvestonense, Triloculina trigonula, Quinqueloculina bosciana,* and *Quinqueloculina poeyana.* Sixty-seven species occur at station 4, 52 in each sample.

Station 5—The rotalids are less numerous at station 5, and the Discorbidae represent about 7% of the fauna. The miliolids are most numerous, and the Elphidiidae are about as common as the Rotaliidae. A general increase in Miliolidae and decrease in the Rotaliidae carries through to the other bay fauna stations. There are 76 species at this station, with 71 species in the "A" sample and 44 species in the "B" sample. The brackish water *Ammonia beccarii* and *Elphidium gunteri galvestonense* are still the most common, but the Miliolidae is the most common family with *Quinqueloculina bosciana, Q. lamarckiana,* and *Q. poeyana* present. The only specimen of *Bolivina hastata* observed occurs here.

Station 6—The foraminiferal number is highest at station 6 and the sediments are the finest. Several species occur only at this station, and include *Pseudonodosaria torrida, Lagena striata, Edentostomina?* sp., *Loxostomum porrectum, Pseudobolivina walshi,* and *Fissurina quadricostulata.* Other very rare specimens present here are *Ammotium salsum, Triloculina gracilis, Stetsonia minuta, Spirillina denticulata, Cibicides refulgens, Buliminoides williamsoniana,* and *Quinqueloculina parkeri occidentalis.* The agglutinated species, *Ammotium salsum, Pseudobolivina walshi,* and *Reophax nana,* are present here, in part, due to the fine sediments available as test-building material. The Miliolidae are the most common followed by the Rotaliidae, Elphidiidae, Bolivinitidae, and Caucasinidae. *Ammonia beccarii* is still most abundant, but *Elphidium gunteri galvestonense* is much less common. Next in abundance to *Ammonia* are *Cribroelphidium poeyanum, Quinqueloculina bosciana, Triloculina trigonula,* and *Quinqueloculina poeyana.* There are 105 species at station 6, 94 species in the "A" sample and 76 species common to the "B" sample.

Station 7—Station 7 is interesting because the number of species present is higher than would be predicted from looking at the coarse fraction and foraminiferal numbers. Possibly this is due to station 7's highly favorable position. It contains a bay fauna but offshore species are carried in by the tidal currents. There are 108 species at station 7, 100 species from the "A" sample and 67 species from the "B" sample. *Quinqueloculina poeyana* is the most common, followed by *Elphidium gunteri galvestonense,* the *Ammonia beccarii* subspecies, *Cribroelphidium poeyanum, Triloculina trigonula,* and *Quinqueloculina bosciana. Peneroplis carinatus* and *Asterigerina carinata* are common. The only occurrences observed of *Loxostomum* sp., *Cibicides deprimus, Bulimina* cf. *B. spicata,* and *Articulina mayori* are at station 7. Very rare specimens of *Articulina multilocularis* and *Articulina lineata* are also here. The family abundance, in decreasing order, is Miliolidae, Elphidiidae, Rotaliidae, Discorbidae, and Soritidae.

Station 8—The distribution of families is the same as for station 7, and this station is also near tidal currents. The Miliolidae are most abundant, followed by the Elphidiidae, Rotaliidae, Discorbidae, and Soritidae. Common in this bay fauna are *Ammonia beccarii* subspp., *Cribroelphidium poeyanum, Discorbis mira, Elphidium gunteri galvestonense, Quinqueloculina lamarckiana, Q. poeyana,* and *Triloculina trigonula.* There are 89 species at this station, 87 species in the "A" sample and 61 species in the "B" sample.

Station 9—This station is within the Norris Cut channel and distribution is strongly affected by tidal currents. The coarser sediments are a result of current sorting. Many of the specimens are very worn and appear older, and possibly have been exposed by the currents cutting into older shoal material. Several very rare specimens, expected to occur only in deeper offshore waters, are present in the samples at this station, and serve as evidence for inshore transport and mixing of offshore and inshore faunas. Miliolids are most prevalent, but the Soritidae are now second-most common, followed by Discorbidae, Asterigerinidae, and Elphidiidae. Very common are *Archaias angulatus, Asterigerina carinata, Discorbis mira, Peneroplis carinatus, Quinqueloculina lamarckiana,* and *Textularia agglutinans.* Very rare forms present are *Astrononion stelligerum, Guttulina australis, Nonion barleeanum, Pyrgo comata,* and an unidentified yellow-colored attached form. Eighty-nine species are present at station 9, and the "A" sample contains 75 species; the "B" sample, 58 species.

Station 10—The Elphidiidae dominate at this station but most are *Cribroelphidium poeyanum,* an accepted bay fauna indicator. Following in abundance are the Miliolidae, Rotaliidae, and Bolivinitidae. Seventy species occur at this station, 58 in the "A" sample and 52 in the "B" sample. Common species include the *Ammonia beccarii* subspp., *Elphidium gunteri galvestonense, Quinqueloculina poeyana,* and *Triloculina trigonula.* The only observed occurrence of *Fissurina* sp. "B" is here.

Station 11—The miliolids dominate at this station, but there are also appreciable numbers of the following families: Discorbidae, Elphidiidae, Rotaliidae, Soritidae, Cibicididae, and Bolivinitidae. Common species are the subspecies of *Ammonia beccarii, Articulina sagra, Cibicides floridana, Cribroelphidium poeyanum, Discorbis mira, Hanzawaia strattoni, Miliolinella circularis, Peneroplis carinatus, Quinqueloculina bosciana, Q. lamarckiana, Q. poeyana,* and *Triloculina trigonula.* Rare species in the sample include *Guttulina australis* and *Rectobolivina advena,* both of them offshore species transported into the bay. There are 96 species at this station, 88 species associated together in the "A" sample and 71 species present in the "B" sample.

Station 12—Stations 12 through 15 were sampled only on May 22, 1973, so no "A" samples exist for these stations. Soritidae are in greater abundance than the Miliolidae at station 12. The large number of Discorbidae are mostly *Discorbis mira* and *Discorbis rosea. Asterigerina carinata,* family Asterigerinidae, is also very common. The major species present, though, are *Peneroplis carinatus* and *Archaias angulatus,* either

transported in from offshore or present as a relict fauna (no live Soritidae have been found within the study area). There are fifty-four species present at this station.

Station 13—This station is strongly swept by the tidal currents in Bear Cut. No vegetation is observed anywhere nearby and the sediments are very coarse in size. The Soritidae are the most common, followed by the Miliolidae, Discorbidae, and Asterigerinidae. *Archaias angulatus* accounts for one-quarter of the specimens, and other species present include *Asterigerina carinata, Discorbis mira, Peneroplis carinatus, Quinqueloculina lamarckiana,* and *Discorbis rosea.* Again, the specimens are probably a relict fauna or else are transported in by waves and currents. Forty-five species occur at this station.

Station 14—This station is south of station 13 and is also affected by the tidal currents moving through Bear Cut. The Miliolidae predominate, followed in abundance by the Discorbidae, Elphidiidae, Soritidae, Asterigerinidae, Amphisteginidae, and Cibicididae. Common species are *Amphistegina lessonii, Articulina mucronata, Asterigerina carinata, Cibicides floridana, Discorbis mira, Elphidium gunteri galvestonense, Quinqueloculina lamarckiana, Q. poeyana, Triloculina linneiana,* and *T. trigonula.* There are 59 species present in the sample from station 14.

Station 15—Percentages of abundance are more evenly spread out for station 15. The Miliolidae are the most numerous, followed in decreasing abundance by the Elphidiidae, Rotaliidae, Nonionidae, Soritidae, Anomalinidae, Discorbidae, and Cibicididae. *Ammonia beccarii tepida* is the most common species, and *Cribroelphidium poeyanum* is very abundant. Other numerous species include *Cibicides floridana, Elphidium gunteri galvestonense, Hanzawaia strattoni, Quinqueloculina bosciana, Q. poeyana,* and *Triloculina trigonula.* Considered a bay fauna station, 67 species are identified from the sample.

VI. CONCLUSIONS

There are 35 families, 75 genera, and 152 species represented in the sediments from the northern Biscayne Bay waters of the study area. The following species have not been reported previously in the area, but are now shown to occur in South Florida waters: *Ammotium salsum, Bulimina marginata, Buliminoides williamsoniana, Cibicides deprimus, Cribroelphidium kugleri, Edentostomina?* sp., *Elphidium gunteri galvestonense, Fissurina radiata, Fissurina* sp. "A", *Guttulina laevis, Hanzawaia strattoni, Lagena laevis, Nonion barleeanum, Nonionella opima, Pseudobolivina walshi, Quinqueloculina auberiana, Reophax nana, Rosalina candeiana, Rotalia dubia, Rotaliammina mayori, Siphogenerina costata, Spiroloculina antillarum angulata, Stetsonia minuta, Textularia parvula,* and an unidentified, yellow-colored, attached form.

Salinity is an important population factor within the northern Biscayne Bay, and variations within the bay are evident from the three faunal assemblages that have been established. The subspecies of *Ammonia beccarii* and *Elphidium gunteri galvestonense* dominate the western bay margin brackish waters, but the Miliolidae are most numerous at the bay fauna stations and the Peneroplidae become increasingly numerous at the eastern bay margin stations, where more oceanic saline conditions prevail.

Current and wave sorting distribute foraminifer tests in the same manner as the sediments are distributed. Inspection of the coarse fraction and foraminiferal number data also shows that, as average sediment grain size increases, fewer tests and fewer species occur in the sample. Inclusion of foraminiferal tests of normally deep water species within the shallow bay waters indicates the presence of the active process of inshore transport at the bay's eastern margin.

Discussing the distribution of a foraminiferal assemblage in detail is not an easy task, as the ecological factors are often interrelated. Moore (1957, p. 740) recognized the necessity of examining those factors controlling the distribution of living foraminifers and those factors controlling the accumulation of the empty tests of dead foraminifers, since "the relationship between these two is critical to distribution". Detailed sampling is the best procedure for determining these factors and evaluating the distribution and frequency in terms of them.

VII. ACKNOWLEDGMENTS

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VIII. SYSTEMATICS

The classification that follows is patterned after that adopted by Loeblich and Tappan (1964) in the *Treatise on Invertebrate Paleontology.*

Order FORAMINIFERIDA Eichwald, 1830
Suborder TEXTULARIINA Delage and Hérouard, 1896
Superfamily LITUOLACEA de Blainville, 1825
Family HORMOSINIDAE Haeckel, 1894
Subfamily HORMOSININAE Haeckel, 1894

Genus REOPHAX Montfort, 1808

REOPHAX NANA Rhumbler
Plate 1, fig. 1

Reophax nana RHUMBLER, 1911, Plankton-Exped. Humboldt-Stiftung, vol. 3, p. 182, pl. 8, figs. 6-12.

Discussion: This species occurred at ten stations, generally in very low frequencies.

Family RZEHAKINIDAE Cushman, 1933
Genus MILIAMMINA Heron-Allen and Earland, 1930

MILIAMMINA FUSCA (Brady)
Plate 1, figs. 2, 3

Quinqueloculina fusca BRADY, 1870, Ann. Mag. Nat. Hist., ser. 4, vol. 6, p. 286, pl. 11, figs. 2, 3.

Miliammina fusca (Brady). PHLEGER and WALTON, 1950, Amer. Jour. Sci., vol. 248, p. 47, pl. 1, fig. 19.

Discussion: This species occurred at 13 stations, generally in low frequencies.

Family LITUOLIDAE de Blainville, 1825
Subfamily HAPLOPHRAGMOIDINAE Maync, 1952

Genus HAPLOPHRAGMOIDES Cushman, 1910

HAPLOPHRAGMOIDES CANARIENSIS (d'Orbigny)

Nonionina canariensis D'ORBIGNY, 1839, *in* BARKER-WEBB and BERTHELOT, Hist. Nat. Iles Canaries, vol. 2, pt. 2, p. 128, pl. 2, figs. 33, 34.

Haplophragmoides canariensis (d'Orbigny). CUSHMAN, 1910, U.S. Natl. Mus., Bull. 71, pt. 1, p. 101, fig. 149.

Discussion: Single specimens were found at stations 1 and 7.

Subfamily LITUOLINAE de Blainville, 1825

Genus AMMOBACULITES Cushman, 1910

AMMOBACULITES AGGLUTINANS (d'Orbigny)

Spirolina agglutinans D'ORBIGNY, 1846, Foram. Foss. Bass. Tert. Vienne, p. 137, pl. 7, figs. 10-12.

Ammobaculites agglutinans (d'Orbigny). CUSHMAN, 1910, U.S. Natl. Mus., Bull. 71, pt. 1, p. 115, fig. 176.

Discussion: This species occurred at seven stations in very low frequencies. Grain size of the test-wall varies among specimens and appears dependent on the material available at each station.

Genus AMMOTIUM Loeblich and Tappan, 1953

AMMOTIUM SALSUM (Cushman and Bronnimann)
Plate 1, fig. 4

Ammobaculites salsus CUSHMAN and BRONNIMANN, 1948, Contr. Cushman Lab. Foram. Res., vol. 24, p. 16, pl. 3, figs. 7-9.

Discussion: This species occurred at only three stations and was very rare.

Family TEXTULARIIDAE Ehrenberg, 1838
Subfamily TEXTULARIINAE Ehrenberg, 1838
Genus TEXTULARIA Defrance, 1824

TEXTULARIA AGGLUTINANS d'Orbigny
Plate 1, fig. 5

Textularia agglutinans D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 144, pl. 1, figs. 17, 18, 32-34.

Discussion: This species occurred at 11 stations, normally in low frequencies. It accounted for over 5% of the "9A" sample, however.

TEXTULARIA PARVULA Cushman
Plate 1, fig. 6

Textularia parvula CUSHMAN, 1922, U.S. Natl. Mus., Bull. 104, pt. 3, p. 11, pl. 6, figs. 1, 2.

Discussion: This species occurred at ten stations in very low frequencies.

Genus BIGENERINA d'Orbigny, 1826

BIGENERINA IRREGULARIS
Phleger and Parker

Bigenerina irregularis PHLEGER and PARKER, 1951, Geol. Soc. America, Mem. 46, pt. 2, p. 4, pl. 1, figs. 16-21.

Discussion: This species occurred in low frequencies at stations 9 and 12. It normally occurs deeper offshore and its presence in the study area indicates inshore transport.

Subfamily PSEUDOBOLIVININAE Wiesner, 1931
Genus PSEUDOBOLIVINA Wiesner, 1931

PSEUDOBOLIVINA WALSHI (Seiglie)
Plate 1, fig. 7

Parvigenerina walshi SEIGLIE, 1971, Rev. Española Micr., vol. 3, no. 3, p. 268, pl. 3, figs. 9-15.

Discussion: This species occurred only at station 6, and was very rare.

Family TROCHAMMINIDAE Schwager, 1877
Subfamily TROCHAMMININAE Schwager, 1877
Genus TROCHAMMINA Parker and Jones, 1859

TROCHAMMINA SP.

Discussion: Single specimens were found at stations 1 and 6.

Genus ROTALIAMMINA Cushman, emend. Loeblich and Tappan, 1955

ROTALIAMMINA MAYORI Cushman
Plate 1, figs. 8, 9

Rotaliammina mayori CUSHMAN, 1924, Carnegie Inst. Washington, Publ. 342, p. 11, pl. 1, figs. 4, 5.

Rotaliammina mayori Cushman, emend. LOEBLICH and TAPPAN, 1955, Smithsonian Inst., Misc. Coll., vol. 128, no. 5, p. 20, pl. 3, fig. 4.

Discussion: This species occurred at ten stations in low to very low frequencies.

Family ATAXOPHRAGMIIDAE Schwager, 1877
Subfamily VALVULININAE Berthelin, 1880
Genus VALVULINA d'Orbigny, 1826

VALVULINA OVIEDOIANA d'Orbigny

Valvulina oviedoiana D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 103, pl. 2, figs. 21, 22.

Discussion: This species occurred at eight stations, but was very rare; in all but one sample only a single specimen was counted.

Genus CLAVULINA d'Orbigny, 1826

CLAVULINA DIFFORMIS (Brady)

Clavulina angularis d'Orbigny var. *difformis* BRADY, 1884, Rept. Voy. *Challenger,* Zool., vol. 9, p. 396, pl. 48, figs. 25-31.

Clavulina difformis (Brady). CUSHMAN, 1921, U.S. Natl. Mus., Bull. 100, vol. 4, p. 156, pl. 31, figs. 2a, b.

Discussion: Single specimens were found at stations 9 and 11.

CLAVULINA TRICARINATA d'Orbigny

Clavulina tricarinata D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 111, pl. 2, figs. 16-18.

Discussion: This species occurred at five stations in very low frequencies.

Suborder MILIOLINA Delage and Hérouard, 1896
Superfamily MILIOLACEA Ehrenberg, 1839
Family FISCHERINIDAE Millett, 1898
Subfamily CYCLOGYRINAE Loeblich and Tappan, 1961

Genus CYCLOGYRA Wood, 1842

CYCLOGYRA INVOLVENS (Reuss)

Plate 1, fig. 10

Operculina involvens REUSS, 1850, Denkschr. Akad. Wiss. Wien., vol. 1, p. 370, pl. 46, fig. 20.

Cyclogyra involvens (Reuss). BOCK, 1971, Miami Geol. Soc., Mem. 1, p. 12, pl. 3, fig. 2.

Discussion: This species occurred at ten stations in very low frequencies.

CYCLOGYRA PLANORBIS (Schultze)

Plate 1, fig. 11

Cornuspira planorbis SCHULTZE, 1854, Organismus Polythal., p. 40, pl. 2, fig. 21.

Cyclogyra planorbis (Schultze). BOCK, 1971, Miami Geol. Soc., Mem. 1, p. 12, pl. 3, fig. 3.

Discussion: This species occurred at 11 stations, and was a little more plentiful than *Cyclogyra involvens.*

Family NUBECULARIIDAE Jones, 1875

Subfamily NUBECULARIINAE Jones, 1875

Genus NUBECULARIA Defrance, 1825

NUBECULARIA cf. N. LUCIFUGA Defrance

Nubecularia lucifuga DEFRANCE, 1825, Dict. Sci. Nat., vol. 35, p. 210.

Discussion: This species occurred at 11 stations, always in frequencies less than 1%. There is considerable variation in size and shape of the test.

Subfamily OPHTHALMIDIINAE Wiesner, 1920

Genus EDENTOSTOMINA Collins, 1958

EDENTOSTOMINA? SP.

Plate 2, figs. 1, 2

Discussion: A single live specimen of this species was found at station 6 in the "A" sample.

Genus WIESNERELLA Cushman, 1933

WIESNERELLA AURICULATA (Egger)

Plate 2, fig. 3

Planispirina auriculata EGGER, 1893, Abhandl. k. bay. Akad. Wiss., München, vol. 18, pt. 2, p. 245, pl. 3, figs. 13-15.

Wiesnerella auriculata (Egger). CUSHMAN, 1933, Contr. Cushman Lab. Foram. Res., vol. 9, p. 33, pl. 3, figs. 7-9.

Discussion: This species occurred at 11 stations and was present in very low frequencies.

Subfamily SPIROLOCULININAE Wiesner, 1920

Genus SPIROLOCULINA d'Orbigny, 1826

SPIROLOCULINA ANTILLARUM d'Orbigny

Plate 2, fig. 4

Spiroloculina antillarum D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 166, pl. 9, figs. 3, 4.

Discussion: This species occurred at six stations but was very rare.

SPIROLOCULINA ANTILLARUM ANGULATA Cushman

Plate 2, fig. 5

Spiroloculina grata BRADY (part) (*not* Terquem), 1884, Rept. Voy. *Challenger,* Zool., vol. 9, pl. 10, figs. 22, 23.

Spiroloculina grata Terquem var. *angulata* CUSHMAN, 1917, U.S. Natl. Mus., Bull. 71, pt. 6, p. 36, pl. 7, fig. 5.

Spiroloculina antillarum d'Orbigny var. *angulata* CUSHMAN, 1921, U.S. Natl. Mus., Bull. 100, vol. 4, p. 408, pl. 81, figs. 5a, b.

Discussion: This species was rare and appeared at seven stations.

SPIROLOCULINA ARENATA Cushman

Plate 2, fig. 6

Spiroloculina arenata CUSHMAN, 1921, Proc. U.S. Natl. Mus., vol. 59, p. 63, pl. 14, fig. 17.

Discussion: This species has an agglutinated wall. It appeared at 11 stations and approached a frequency of 2% at station 11.

Subfamily NODOBACULARIINAE Cushman, 1927

Genus NODOBACULARIELLA Cushman and Hanzawa, 1937

NODOBACULARIELLA CASSIS (d'Orbigny)

Vertebralina cassis D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 51, pl. 7, figs. 14, 15.

Nodobacullariella cassis (d'Orbigny). BOCK, 1971, Miami Geol. Soc., Mem. 1, p. 15, pl. 4, fig. 2.

Discussion: This species occurred at three stations in very low frequencies.

Family MILIOLIDAE Ehrenberg, 1839

Subfamily QUINQUELOCULININAE Cushman, 1917

Genus QUINQUELOCULINA d'Orbigny, 1826

QUINQUELOCULINA AGGLUTINANS d'Orbigny

Quinqueloculina agglutinans D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 195, pl. 12, figs. 11-13.

Discussion: This species occurred at 14 stations, always with frequencies less than 2%.

QUINQUELOCULINA AUBERIANA d'Orbigny

Quinqueloculina auberiana D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 193, pl. 12, figs. 1-3.

Discussion: This species occurred at seven stations, generally in very low frequencies.

QUINQUELOCULINA BICOSTATA d'Orbigny

Quinqueloculina bicostata D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 195, pl. 12, figs. 8-10.

Discussion: This species occurred at five stations in very low frequencies.

QUINQUELOCULINA BIDENTATA d'Orbigny

Quinqueloculina bidentata D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 197, pl. 12, figs. 18-20.

Discussion: Quinqueloculina bidentata differs from *Quinqueloculina agglutinans* by having a more squarely truncate periphery. This species occurred at only two stations in very low frequencies.

QUINQUELOCULINA BOSCIANA d'Orbigny

Plate 2, figs. 7, 8

Quinqueloculina bosciana D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 191, pl. 11, figs. 22-24.

Discussion: This species was ubiquitous and very common. It was the third-most abundant species in the standing crop.

QUINQUELOCULINA COLLUMNOSA Cushman

Miliolina cuvieriana HERON-ALLEN and EARLAND (*not* d'Orbigny), 1915, Trans. Zool. Soc. London, vol. 20, p. 571, pl. 4, figs. 33-36.

Quinqueloculina collumnosa CUSHMAN, 1922, Carnegie Inst. Washington, Publ. 311, p. 65, pl. 10, fig. 10.

Discussion: This species occurred at six stations in very low frequencies.

QUINQUELOCULINA FUNAFUTIENSIS (Chapman)

Plate 2, figs. 9, 10

Miliolina funafutiensis CHAPMAN, 1901, Jour. Linn. Soc. London, Zool., vol. 28, p. 178, pl. 19, fig. 6.

Quinqueloculina funafutiensis (Chapman). CUSHMAN, 1922, Carnegie Inst. Washington, Publ. 311, p. 67, pl. 13, fig. 3.

Discussion: Single specimens of this species were found at five stations.

QUINQUELOCULINA LAMARCKIANA d'Orbigny

Plate 3, figs. 1, 2

Quinqueloculina lamarckiana D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 189, pl. 11, figs. 14, 15.

Discussion: This ubiquitous species was fairly common, and there is considerable variation in the size and shape of the tests.

QUINQUELOCULINA PARKERI OCCIDENTALIS Cushman

Quinqueloculina parkeri (Brady) var. *occidentalis* CUSHMAN, 1921, Proc. U.S. Natl. Mus., vol. 59, p. 69.

Discussion: Single specimens were found at stations 6, 11, and 15.

QUINQUELOCULINA POEYANA d'Orbigny

Plate 3, figs. 3, 4

Quinqueloculina poeyana D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 191, pl. 11, figs. 25-27.

Discussion: This species was common or abundant at every station. It was also fairly common in the standing crop. There is a large range in the size of the tests, and the width to length ratio varies considerably.

QUINQUELOCULINA POLYGONA d'Orbigny

Plate 3, figs. 5, 6

Quinqueloculina polygona D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 198, pl. 12, figs. 21-23.

Discussion: This species occurred at 11 stations in low frequencies, never exceeding 3%.

QUINQUELOCULINA SEMINULUM (Linnaeus)

Serpula seminulum LINNAEUS, 1767, Syst. Nat., ed. 12, p. 1264.

Quinqueloculina seminulum (Linnaeus). D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 303.

Discussion: This species occurred in low frequencies at every station except 13, where it was absent.

QUINQUELOCULINA SUBPOEYANA Cushman

Plate 3, fig. 7

Quinqueloculina subpoeyana CUSHMAN, 1922, Carnegie Inst. Washington, Publ. 311, p. 66.

Discussion: This species occurred at ten stations, always in frequencies less than 1%.

QUINQUELOCULINA TRICARINATA d'Orbigny

Quinqueloculina tricarinata D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 187, pl. 11, figs. 7-9, 11.

Discussion: Single specimens were found at stations 9, 12, and 13. Very possibly they are present as a result of either inshore transport or current scouring into older sediments.

Genus MASSILINA Schlumberger, 1893

MASSILINA SECANS (d'Orbigny)

Quinqueloculina secans D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 303, no. 43.

Massilina secans (d'Orbigny). SCHLUMBERGER, 1893, Mém. Soc. Zool. France, vol. 6, p. 218, pl. 4, figs. 82, 83.

Discussion: A single specimen was found in the "1B" sample.

Genus PYRGO Defrance, 1824

PYRGO CARINATA (d'Orbigny)

Plate 3, fig. 8

Biloculina carinata D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 164, pl. 8, fig. 24; pl. 9, figs. 1, 2.

Discussion: This species occurred at six stations in very low frequencies.

PYRGO COMATA (Brady)

Biloculina comata BRADY, 1884, Rept. Voy. *Challenger,* Zool., vol. 9, p. 144, pl. 3, figs. 9a, b.

Pyrgo comata (Brady). CUSHMAN, 1929, U.S. Natl. Mus., Bull. 104, pt. 6, p. 73.

Discussion: A single specimen was found at station 9. The species normally occurs at much greater depths, and its presence in Norris Cut is probably a result of storms and currents.

PYRGO SUBSPHAERICA (d'Orbigny)

Plate 3, fig. 9

Biloculina subsphaerica D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 162, pl. 8, figs. 25-27.

Pyrgo subsphaerica (d'Orbigny). CUSHMAN, 1929, U.S. Natl. Mus., Bull. 104, pt. 6, p. 68, pl. 18, figs. 1, 2.

Discussion: This ubiquitous species occurred in low frequencies.

Genus TRILOCULINA d'Orbigny, 1826

TRILOCULINA BASSENSIS Parr

Plate 4, figs. 1, 2

Triloculina bassensis PARR, 1945, Proc. Roy. Soc. Victoria, vol. 56, pt. 2, p. 198, pl. 8, fig. 7a-c.

Discussion: This species occurred at 13 stations in low frequencies.

TRILOCULINA BERMUDEZI Acosta

Plate 4, figs. 3, 4

Triloculina bermudezi ACOSTA, 1940, Soc. Cubana Hist. Nat., Mem., vol. 14, p. 37, pl. 4, figs. 1-5.

Discussion: This species occurred at nine stations in frequencies near 1%.

TRILOCULINA BICARINATA d'Orbigny

Triloculina bicarinata D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 158, pl. 10, figs. 18-20.

Discussion: Single specimens were found at stations 9 and 12. A truncate periphery with double keels differentiates this species from *Triloculina carinata,* which has a more carinate periphery.

TRILOCULINA CARINATA d'Orbigny

Triloculina carinata D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 179, pl. 10, figs. 15-17.

Discussion: This species occurred at five stations in very low frequencies.

TRILOCULINA FITERREI MENINGOI Acosta

Plate 4, figs. 5, 6

Triloculina fiterrei Acosta var. *meningoi* ACOSTA, 1940, Torreia, La Habana, Cuba, no. 3, p. 25-26, pl. 4, figs. 1-5.

Discussion: This species occurred at eight stations in low frequencies.

TRILOCULINA GRACILIS d'Orbigny

Triloculina gracilis D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 159, pl. 11, figs. 10-12.

Discussion: Single specimens of this species were found at stations 4, 6, and 14.

TRILOCULINA LINNEIANA d'Orbigny

Triloculina linneiana D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 172, pl. 9, figs. 11-13.

Discussion: This species occurred at ten stations, normally in low frequencies. Frequency was near 4%, however, at stations 9 and 14.

TRILOCULINA LINNEIANA COMIS Bandy

Triloculina linneiana d'Orbigny var. *comis* BANDY, 1956, U.S. Geol. Surv. Prof. Paper 274-G, p. 198 , pl. 29, fig. 12.

Discussion: This species occurred at five stations in very low frequencies. This species is smaller than *Triloculina linneiana;* possesses finer, more numerous longitudinal costae; and has its aperture at the end of an extended cylindrical neck.

TRILOCULINA OBLONGA (Montagu)

Vermiculum oblongum MONTAGU, 1803, Test. Brit., p. 522, pl. 14, fig. 9.

Triloculina oblonga (Montagu). D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 300, no. 16.

Discussion: This species occurred at eight stations in very low frequencies.

TRILOCULINA PLANCIANA d'Orbigny

Triloculina planciana D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 173, pl. 9, figs. 17-19.

Discussion: This species was very rare and occurred at only two stations. It resembles *Triloculina linneiana,* but the ornamentation consists of fine lines and not prominent ridges.

TRILOCULINA ROTUNDA d'Orbigny

Triloculina rotunda D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 299, no. 4.

Discussion: This species occurred at 11 stations but in very low frequencies.

TRILOCULINA SIDEBOTTOMI (Martinotti)

Miliolina subrotunda SIDEBOTTOM (not *Vermiculum subrotundum* Montagu), 1904, Manchester Lit. Phil. Soc., vol. 68, no. 5, p. 8, pl. 3, figs. 1-7.

Sigmoilina sidebottomi MARTINOTTI, 1920, Atti. Soc. Ital. Sci. Nat., vol. 59, p. 280, pl. 2, fig. 29, text-figs. 59-61.

Triloculina sidebottomi (Martinotti). PARKER, PHLEGER and PIERSON, 1953, Cushman Lab. Foram. Res., Spec. Publ. 2, p. 14, pl. 2, figs. 25-28.

Discussion: This species was very rare and occurred only at stations 4, 8, and 9.

TRILOCULINA TRIGONULA (Lamarck)

Plate 4, fig. 7

Miliola trigonula LAMARCK, 1804, Ann. Mus. [Paris], vol. 5, p. 351, no. 3.

Triloculina trigonula (Lamarck). D'ORBIGNY, 1858, Ann. Sci. Nat., vol. 7, p. 299, no. 1, pl. 16, figs. 5-9.

Discussion: This was a common to abundant species and was ubiquitous. It was the second-most common species in the standing crop. There is considerable variation in chamber-form among specimens, ranging from chambers with subacute angles to broadly rounded chambers.

Subfamily MILIOLINELLINAE Vella, 1957

Genus MILIOLINELLA Wiesner, 1931

MILIOLINELLA CIRCULARIS (Bornemann)

Plate 4, fig. 8

Triloculina circularis BORNEMANN, 1855, Geol. Ges. Zeitschr., vol. 7, pt. 2, p. 349, pl. 19, figs. 4a-c.

Miliolinella circularis (Bornemann). ASANO, 1951, Ill. Cat. Jap. Tert. Smaller Foram., pt. 6, p. 9, figs. 65-67.

Discussion: This species was present everywhere except at station 13. Frequency was fairly low but reached 4% at station 5.

MILIOLINELLA FICHTELIANA (d'Orbigny)

Plate 4, fig. 9

Triloculina fichteliana D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 171, pl. 9, figs. 8-10.

Miliolinella fichteliana (d'Orbigny). BOCK, 1971, Miami Geol. Soc., Mem. 1, p. 29, pl. 12, fig. 6.

Discussion: This species occurred at nine stations, but in very low frequencies.

MILIOLINELLA LABIOSA (d'Orbigny)

Plate 5, fig. 1

Triloculina labiosa D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 178, pl. 10, figs. 12-14.

Miliolinella labiosa (d'Orbigny). WIESNER, 1931, Deutsche Sud-Polar Exped., vol. 20, p. 108, pl. 15, figs. 181, 182.

Discussion: This species occurred at ten stations, always in frequencies less than 1%.

MILIOLINELLA SUBORBICULARIS (d'Orbigny)

Triloculina suborbicularis D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 300, no. 12.
Miliolinella suborbicularis (d'Orbigny). BOCK, 1971, Miami Geol. Soc., Mem. 1, p. 30, pl. 12, fig. 8.

Discussion: This species occurred at six stations in very low frequencies.

Subfamily MILIOLINAE Ehrenberg, 1839

Genus HAUERINA d'Orbigny, 1839

HAUERINA BRADYI Cushman
Plate 5, fig. 2

Hauerina bradyi CUSHMAN, 1917, U.S. Natl. Mus., Bull. 71, pt. 6, p. 62, pl. 23, fig. 2.

Discussion: This species was present at 13 stations in low frequencies.

HAUERINA OCCIDENTALIS Cushman
Plate 5, fig. 3

Hauerina ornatissima CUSHMAN (not Karrer), 1929, U.S. Natl. Mus., Bull. 104, pt. 6, p. 47, pl. 10, figs. 10-12.
Hauerina occidentalis CUSHMAN, 1946, Contr. Cushman Lab. Foram. Res., vol. 22, p. 9, pl. 1, figs. 22-24.

Discussion: This species was very rare and occurred only at stations 5, 7, and 9.

HAUERINA SPECIOSA (Karrer)

Spiroloculina speciosa KARRER, 1868, Akad. Wiss. Wien, vol. 58, p. 135, pl. 1, fig. 8.
Hauerina speciosa (Karrer). SAID, 1949, Cushman Lab. Foram. Res., Spec. Publ. 26, p. 17, pl. 2, fig. 10.

Discussion: This rare species occurred only at stations 5 and 11.

Subfamily TUBINELLINAE Rhumbler, 1906

Genus ARTICULINA d'Orbigny, 1826

ARTICULINA ANTILLARUM Cushman

Articulina antillarum CUSHMAN, 1922, Carnegie Inst. Washington, Publ. 311, p. 71, pl. 12, fig. 5.

Discussion: This species was rare and occurred only at four stations.

ARTICULINA LINEATA Brady

Articulina lineata BRADY, 1884, Rept. Voy. *Challenger,* Zool., vol. 9, p. 183, pl. 12, figs. 19-21.

Discussion: Single specimens occurred at stations 7, 11, and 15.

ARTICULINA MAYORI Cushman

Articulina mayori CUSHMAN, 1922, Carnegie Inst. Washington, Publ. 311, p. 71, pl. 13, fig. 5.

Discussion: This species was represented by a single specimen from the "7B" sample.

ARTICULINA MUCRONATA (d'Orbigny)
Plate 5, fig. 4

Vertebralina mucronata D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 52, pl. 7, figs. 16-19.
Articulina mucronata (d'Orbigny). CUSHMAN, 1944, Cushman Lab. Foram. Res., Spec. Publ. 10, p. 12, pl. 2, figs. 11-18.

Discussion: This species occurred at 13 stations in low frequencies.

ARTICULINA MULTILOCULARIS Brady, Parker and Jones
Plate 5, fig. 5

Articulina multilocularis BRADY, PARKER and JONES, 1888, Trans. Zool. Soc. London, vol. 12, p. 215, pl. 40, fig. 10.

Discussion: This species was very rare, with single specimens occurring at stations 2, 7, and 8.

ARTICULINA SAGRA d'Orbigny
Plate 5, fig. 6

Articulina sagra D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 183, pl. 9, figs. 23-26.

Discussion: This species occurred at 12 stations in low frequencies.

Family SORITIDAE Ehrenberg, 1839

Subfamily PENEROPLINAE Schultze, 1854

Genus PENEROPLIS Montfort, 1808

PENEROPLIS BRADYI Cushman
Plate 5, fig. 7

Peneroplis bradyi CUSHMAN, 1930, U.S. Natl. Mus., Bull. 104, pt. 7, p. 40, pl. 14, figs. 8-10.

Discussion: This species occurred in low frequencies at eight stations.

PENEROPLIS CARINATUS d'Orbigny
Plate 5, fig. 8

Peneroplis carinatus D'ORBIGNY, 1839, Voy. Amer. Merid., vol. 5, pt. 5, p. 33, pl. 3, figs. 7, 8.

Discussion: Frequencies ranged from low to abundant for this species. Absent only

from station 3, abundance increased toward the channel stations.

PENEROPLIS PERTUSUS (Forskal)

Plate 5, fig. 9

Nautilus pertusus FORSKAL, 1775, Descr. Anim., p. 125, no. 65.

Peneroplis pertusus (Forskal). JONES, PARKER and BRADY, 1865, Foram. Crag, p. 19.

Discussion: This species was present at 12 stations in low to very low frequencies.

PENEROPLIS PROTEUS d'Orbigny

Plate 6, fig. 1

Peneroplis protea D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 60, pl. 7, figs. 7-11.

Peneroplis proteus d'Orbigny . CUSHMAN, 1921, Proc. U.S. Natl. Mus., vol. 59, p. 75, pl. 18, figs. 13-19.

Discussion: This species occurred at eight stations in low to very low frequencies.

Genus MONALYSIDIUM Chapman, 1900

MONALYSIDIUM POLITUM (Chapman)

Peneroplis (Monalysidium) polita CHAPMAN, 1900, Jour. Linn. Soc. London, Zool., vol. 28, no. 179, p. 4, pl. 1, fig. 5.

Monalysidium politum (Chapman). HERON-ALLEN and EARLAND, 1915, Trans. Zool. Soc. London, vol. 20, p. 603.

Discussion: This species occurred at six stations, generally a single specimen at each.

Genus SPIROLINA Lamarck, 1804

SPIROLINA ACICULARIS (Batsch)

Plate 6, fig. 2

Nautilus (Lituus) acicularis BATSCH, 1791, Conch. Seesandes, p. 34, pl. 6, fig. 16.

Spirolina acicularis (Batsch). CUSHMAN, 1930, U.S. Natl. Mus., Bull. 104, pt. 7, p. 42, pl. 15, figs. 1-3.

Discussion: This species occurred at four stations and was rare.

SPIROLINA ARIETINUS (Batsch)

Nautilus (Lituus) arietinus BATSCH, 1791, Conch. Seesandes, p. 34, pl. 6, fig. 15.

Spirolina arietinus (Batsch). CUSHMAN, 1930, U.S. Natl. Mus., Bull. 104, pt. 7, p. 43, pl. 15, figs. 4, 5.

Discussion: Single specimens of this species were found at stations 7 and 9.

Subfamily MEANDROPSININAE Henson, 1948

Genus BROECKINA Munier-Chalmas, 1882

BROECKINA ORBITOLITOIDES (Hofker)

Praesorites orbitolitoides HOFKER, 1930, *Siboga*-Expédite, pt. 2, p. 149, pl. 55, figs. 8, 10, 11; pl. 57, figs. 4, 6; pl. 58, figs. 1-5; pl. 61, figs. 3, 14.

Broeckina orbitolitoides (Hofker). BOCK, 1971, Miami Geol. Soc., Mem. 1, p. 35, pl. 13, fig. 15.

Discussion: This species occurred at six stations in very low frequencies.

Subfamily ARCHAIASINAE Cushman, 1927

Genus ARCHAIAS Montfort, 1808

ARCHAIAS ANGULATUS (Fichtel and Moll)

Plate 6, fig. 3

Nautilus angulatus FICHTEL and MOLL, 1803, Test. Micr., 2nd ed., p. 112, pl. 21.

Archaias angulatus (Fichtel and Moll). CUSHMAN, 1928, Cushman Lab. Foram. Res., Spec. Publ. 1, p. 218, pl. 31, fig. 9.

Discussion: This species occurred at ten stations, and frequency was variable. *Archaias angulatus* was rare within the northern bay but was common within the channels. The increased numbers are probably due to scouring and exposure of older material or inshore transport from the offshore shoal areas.

Genus CYCLORBICULINA Silvestri, 1937

CYCLORBICULINA COMPRESSA (d'Orbigny)

Orbiculina compressa D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 66, pl. 8, figs. 4-7.

Archaias compressus (d'Orbigny). CUSHMAN, 1930, U.S. Natl. Mus., Bull. 104, pt. 7, p. 48, pl. 17, figs. 1, 2.

Cyclorbiculina compressa (d'Orbigny). LOEBLICH and TAPPAN, 1964, Treat. Invert. Paleont., p. C495, fig. 383, 1-3.

Discussion: This species occurred at four stations in very low frequencies.

Subfamily SORITINAE Ehrenberg, 1839

Genus SORITES Ehrenberg, 1839

SORITES MARGINALIS (Lamarck)

Plate 6, fig. 4

Orbulites marginalis LAMARCK, 1816, Syst. Anim. sans Vert., vol. 2, p. 196, no. 1.
Orbitolites marginalis (Lamarck). CARPENTER, 1883, Philos. Trans., vol. 174, p. 560, fig. 1.
Sorites marginalis (Lamarck). CUSHMAN, 1930, U.S. Natl. Mus., Bull. 104, pt. 7, p. 49, pl. 18, figs. 1-4.

Discussion: This species occurred at nine stations in low to very low frequencies.

Family ALVEOLINIDAE Ehrenberg, 1839
Genus BORELIS Montfort, 1808
BORELIS PULCHRA (d'Orbigny)

Alveolina pulchra D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 70, pl. 8, figs. 19, 20.
Borelis pulchra (d'Orbigny). CUSHMAN, 1930, U.S. Natl. Mus., Bull. 104, pt. 7, p. 55, pl. 15, figs. 9, 10.

Discussion: This species occurred at six stations in low to very low frequencies.

Suborder ROTALIINA Delage and Herouard, 1896
Superfamily NODOSARIACEA Ehrenberg, 1838
Family NODOSARIIDAE Ehrenberg, 1838
Subfamily NODOSARIINAE Ehrenberg, 1838
Genus LAGENA Walker and Jacob, 1798
LAGENA LAEVIS (Montagu)
Plate 6, fig. 5

Vermiculum laeve MONTAGU, 1803, Test. Brit., p. 524.
Lagena laevis (Montagu). CUSHMAN, 1923, U.S. Natl. Mus., Bull. 104, pt. 4, p. 29, pl. 5, fig. 3.

Discussion: This species was present at three stations in very low frequencies.

LAGENA STRIATA (d'Orbigny)

Oolina striata D'ORBIGNY, 1839, Voy. Amer. Merid., vol. 5, pt. 5, p. 21, pl. 5, fig. 12.
Lagena striata (d'Orbigny). REUSS, 1862, Sitz. Akad. Wiss. Wien, vol. 46, pt. 1, p. 327, pl. 3, figs. 44, 45; pl. 4, figs. 46, 47.

Discussion: A single live specimen of this species was found in the "6A" sample.

Genus PSEUDONODOSARIA Boomgaart, 1949
PSEUDONODOSARIA TORRIDA (Cushman)

Nodosaria (Glandulina) laevigata d'Orbigny var. *torrida* CUSHMAN, 1923, U.S. Natl. Mus., Bull. 104, pt. 4, p. 65, fig. 10.
Rectoglandulina torrida (Cushman). BARKER, 1960, S.E.P.M., Spec. Publ. 9, pl. 61, figs. 20-22.
Pseudonodosaria torrida (Cushman). BOCK, 1971, Miami Geol. Soc., Mem. 1, p. 42, pl. 15, fig. 13.

Discussion: A single specimen was found in the "6A" sample.

Family POLYMORPHINIDAE d'Orbigny, 1839
Subfamily POLYMORPHININAE d'Orbigny, 1839
Genus GUTTULINA d'Orbigny, 1839
GUTTULINA AUSTRALIS (d'Orbigny)

Globulina australis D'ORBIGNY, 1839, Voy. Amer. Merid., vol. 5, pt. 5, p. 60, pl. 1, figs. 1-4.
Guttulina australis (d'Orbigny). BOCK, 1971, Miami Geol. Soc., Mem. 1, p. 43, pl. 16, fig. 2.

Discussion: Single specimens of *Guttulina australis* were found at stations 9 and 11.

GUTTULINA LAEVIS de Pourtales
Plate 6, fig. 6

Guttulina laevis DE POURTALES, 1850, Amer. Assoc. Adv. Sci., Proc., vol. 3, p. 88.

Discussion: This species occurred at seven stations in very low frequencies.

Family GLANDULINIDAE Reuss, 1860
Subfamily OOLININAE Loeblich and Tappan, 1961
Genus FISSURINA Reuss, 1850
FISSURINA cf. F. LUCIDA (Williamson)
Plate 6, fig. 7

Entosolenia marginata (Montagu) var. *lucida* WILLIAMSON, 1848, Ann. Mag. Nat. Hist., ser. 2, vol. 1, p. 17, pl. 2, fig. 17.
Fissurina marginata Montagu var. *lucida* (Williamson). LYNTS, 1971, Miami Geol. Soc., Mem. 1, p. 89.

Discussion: This species occurred at 11 stations in low frequencies.

FISSURINA PELLUCIDA Bock

Fissurina pellucida BOCK, 1968, Contr. Cushman Found. Foram. Res., vol. 19, p. 28, pl. 4, figs. 1, 2.

Discussion: This species occurred at five stations and was rare.

FISSURINA QUADRICOSTULATA (Reuss)

Lagena quadricostulata REUSS, 1870, Sitzb. Akad. Wiss. Wien, vol. 62, p. 469.

Fissurina quadricostulata (Reuss). WRIGHT and HAY, 1971, Miami Geol. Soc., Mem. 1, p. 145.

Discussion: Two specimens of this species were found at station 6.

FISSURINA RADIATA Seguenza

Fissurina (Produttine) radiata SEGUENZA, 1862, Terz. dist. Messina, p. 70, pl. 2, figs. 42-43.

Discussion: A single specimen of this species appeared at station 15.

FISSURINA sp. "A"

Plate 6, fig. 8

Discussion: Single specimens of this species were found at stations 5, 6, 7, 10, and 15.

FISSURINA sp. "B"

Discussion: Two specimens of this very rare species were found at station 10 in the "A" sample.

Superfamily BULIMINACEA Jones, 1875

Family TURRILINIDAE Cushman, 1927

Subfamily TURRILININAE Cushman, 1927

Genus BULIMINELLA Cushman, 1911

BULIMINELLA ELEGANTISSIMA (d'Orbigny)

Plate 6, fig. 9

Bulimina elegantissima D'ORBIGNY, 1839, Voy. Amer. Merid., vol. 5, pt. 5, p. 51, pl. 7, figs. 13, 14.

Buliminella elegantissima (d'Orbigny). PHLEGER and PARKER, 1951, Geol. Soc. America, Mem. 46, pt. 2, p. 17, pl. 8, figs. 3, 4.

Discussion: This species occurred at nine stations in very low frequencies.

BULIMINELLA MILLETTI Cushman

Plate 7, fig. 1

Buliminella milletti CUSHMAN, 1933, Contr. Cushman Lab. Foram. Res., vol. 9, p. 78, pl. 8, figs. 5, 6.

Discussion: This species was present at nine stations in low frequencies.

Genus BULIMINOIDES Cushman, 1911

BULIMINOIDES WILLIAMSONIANA (Brady)

Plate 7, fig. 2

Bulimina williamsoniana BRADY, 1881, Quart. Jour. Micr. Soc., vol. 21, p. 56.

Buliminoides williamsoniana (Brady). CUSHMAN, 1911, U.S. Natl. Mus., Bull. 71, pt. 2, p. 90, fig. 144.

Discussion: Single specimens of this species were present at stations 6, 7, and 14.

PLATE 1

Figure Page

1. *Reophax nana* Rhumbler.
   Sample 2A, Side view, X225 271
2,3. *Miliammina fusca* (Brady).
   Sample 2B, fig. 2, Side view, X250, fig. 3, Side view, X270 271
4. *Ammotium salsum* (Cushman and Bronnimann).
   Sample 10A, Side view, X135 271
5. *Textularia agglutinans* d'Orbigny.
   Sample 9A, Side view, X110 272
6. *Textularia parvula* Cushman.
   Sample 7A, Side view, X100 272
7. *Pseudobolivina walshi* (Seiglie).
   Sample 6A, Side view, X175 272
8,9. *Rotaliammina mayori* Cushman.
   Sample 6A, fig. 8, Ventral view, X225,
   Sample 9A, fig. 9, Dorsal view, attached, X260 272
10. *Cyclogyra involvens* (Reuss).
   Sample 6B, Side view, X295 273
11. *Cyclogyra planorbis* (Schultze).
   Sample 6A, Side view, X225 273

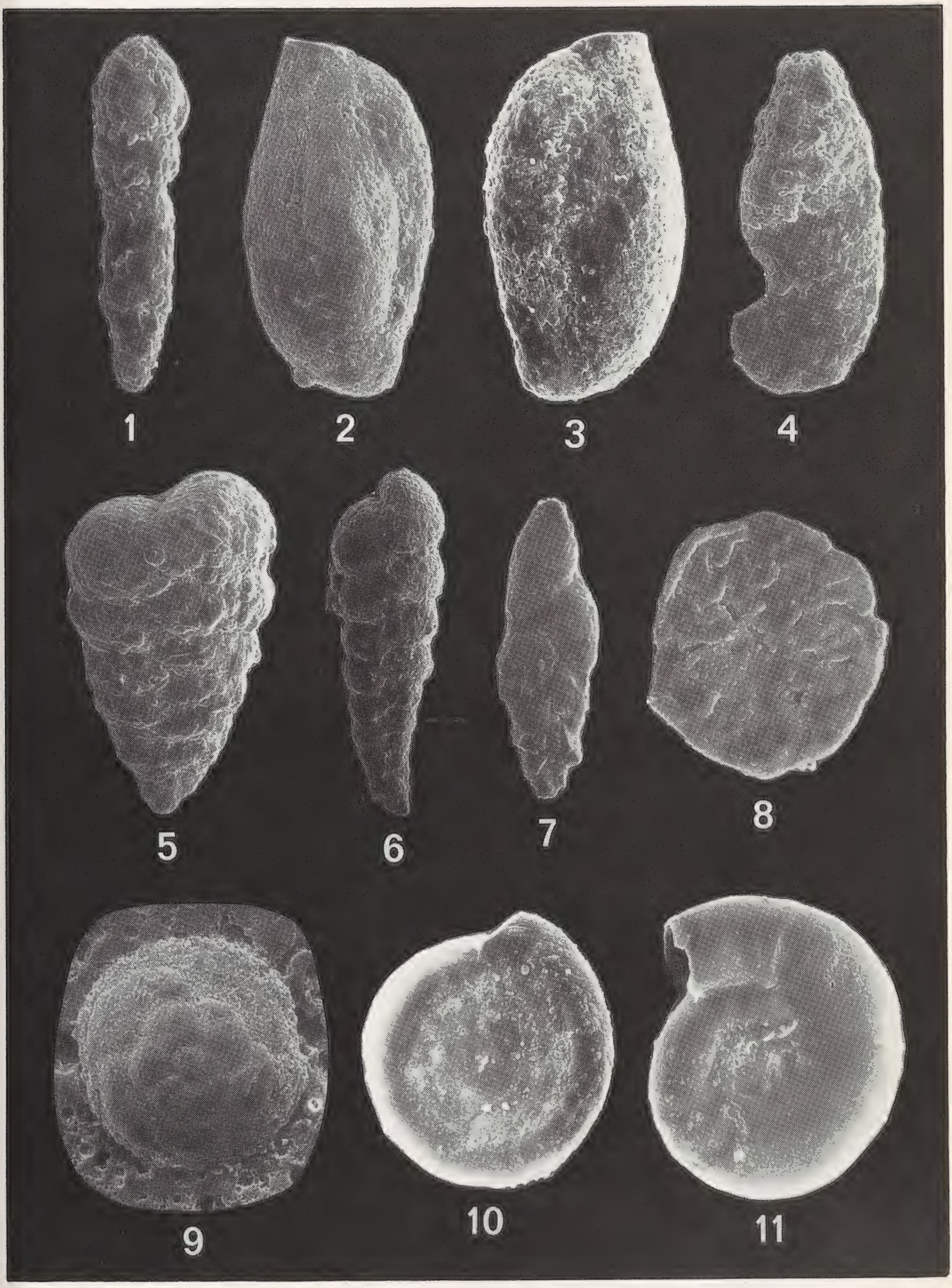

PLATE 1

Family BOLIVINITIDAE Cushman, 1927
Genus BOLIVINITA Cushman, 1927

BOLIVINITA RHOMBOIDALIS (Millett)
Plate 7, fig. 3

Textularia rhomboidalis MILLETT, 1899, Jour. Roy. Micr. Soc., p. 559, pl. 7, fig. 4a, b.
Bolivina rhomboidalis (Millett). CUSHMAN, 1922, Carnegie Inst. Washington, Publ. 311, p. 28.

Discussion: This species occurred at 12 stations in low to very low frequencies.

Genus BOLIVINA d'Orbigny, 1839

BOLIVINA GOESII Cushman, 1922

Bolivina goesii CUSHMAN, 1922, U.S. Natl. Mus., Bull. 104, pt. 3, p. 34, pl. 6, fig. 5.

Discussion: Four specimens of this species were found at station 4, and only one specimen each at stations 5 and 6.

BOLIVINA HASTATA Phleger and Parker

Bolivina hastata PHLEGER and PARKER, 1951, Geol. Soc. America, Mem. 46, pt. 2, p. 13, pl. 6, figs. 18, 19.

Discussion: A single specimen of this species was found at station 5.

BOLIVINA LANCEOLATA Parker
Plate 7, fig. 4

Bolivina lanceolata PARKER, 1954, Bull. Harvard Mus. Comp. Zool., vol. 111, no. 10, p. 514, pl. 7, figs. 17-20.

Discussion: This species occurred at 11 stations in low to very low frequencies.

BOLIVINA LOWMANI Phleger and Parker

Bolivina lowmani PHLEGER and PARKER, 1951, Geol. Soc. America, Mem. 46, pt. 2, p. 13, pl. 6, figs. 20, 21.

Discussion: This species occurred at 13 stations in low frequencies.

BOLIVINA PAULA Cushman and Cahill

Bolivina paula CUSHMAN and CAHILL, 1932, Bull. Florida Geol. Surv., vol. 9, p. 84, pl. 12, fig. 6.

Discussion: This species was present at 12 stations in low to very low frequencies.

BOLIVINA STRIATULA Cushman
Plate 7, fig. 5

Bolivina striatula CUSHMAN, 1922, Carnegie Inst. Washington, Publ. 311, p. 27, pl. 3, fig. 10.

Discussion: Bolivina striatula was present at 11 stations in low to very low frequencies.

Genus RECTOBOLIVINA Cushman, 1927

RECTOBOLIVINA ADVENA (Cushman)

Siphogenerina advena CUSHMAN, 1922, Carnegie Inst. Washington, Publ. 311, p. 35, pl. 5, fig. 2.
Rectobolivina advena (Cushman). HOFKER, 1951, Vitkom. Zool., Bot. Oceanogr., Geol. Geb., Nederlandsch., Mon. 4a, p. 116, 232.

Discussion: A single specimen of this species was found in the "11b" sample.

Family BULIMINIDAE Jones, 1875
Subfamily BULIMININAE Jones, 1875
Genus BULIMINA d'Orbigny, 1826

BULIMINA MARGINATA d'Orbigny
Plate 7, fig. 6

PLATE 2

Figure Page

1,2. *Edentostomina?* sp.
Sample 6A, fig. 1, Side view, X135, fig. 2, Apertural view, X110 273
3. *Wiesnerella auriculata* (Egger).
Sample 6A, Side view, X295 273
4. *Spiroloculina antillarum* d'Orbigny.
Sample 8B, Side view, X90 273
5. *Spiroloculina antillarum angulata* Cushman.
Sample 7B, Side view, X90 273
6. *Spiroloculina arenata* Cushman.
Sample 8A, Side view, X135 273
7,8. *Quinqueloculina bosciana* d'Orbigny.
Sample 5B, Side views, X115 274
9,10. *Quinqueloculina funafutiensis* (Chapman).
Sample 12B, fig. 9, Side view, X90, fig. 10, Apertural view, X135 274

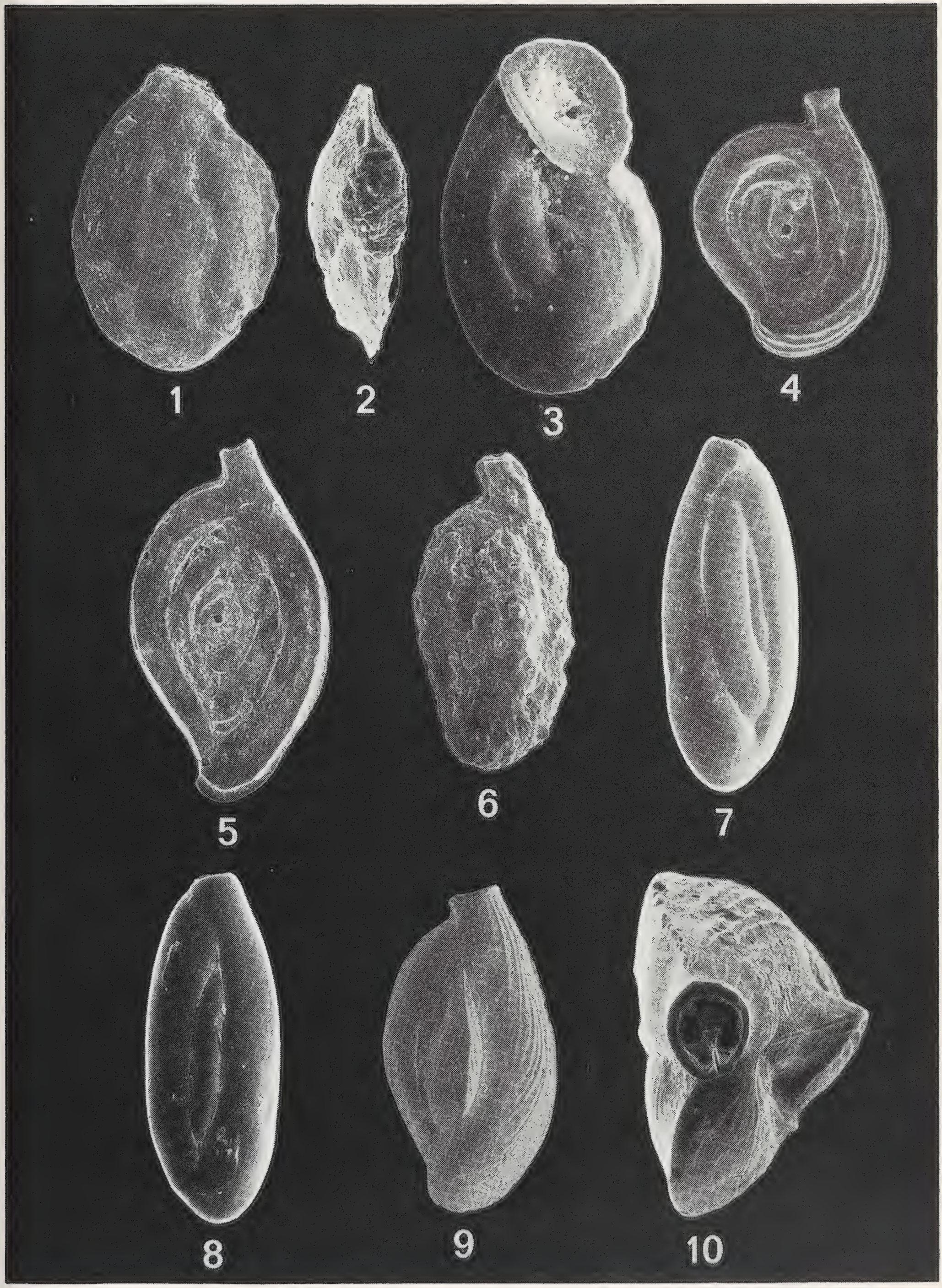

PLATE 2

Bulimina marginata D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 269, no. 4, pl. 12, figs. 10-12.

Discussion: This species occurred at four stations in very low frequencies.

BULIMINA cf. B. SPICATA
Phleger and Parker

Bulimina spicata PHLEGER and PARKER, 1951, Geol. Soc. America, Mem. 46, pt. 2, p. 16, pl. 7, figs. 25, 30, 31.

Discussion: A single specimen of this species was present at station 7.

Subfamily PAVONININAE Eimer and Fickert, 1899

Genus REUSSELLA Galloway, 1933

REUSSELLA ATLANTICA Cushman

Reussella spinulosa (Reuss) var. *atlantica* CUSHMAN, 1947, Contr. Cushman Lab. Foram. Res., vol. 23, p. 91, pl. 20, figs. 6, 7.

Reussella atlantica Cushman. BANDY, 1954, U.S. Geol. Survey Prof. Paper 254-F, p. 138, pl. 31, fig. 7.

Discussion: This species occurred at nine stations in very low frequencies.

Family UVIGERINIDAE Haeckel, 1894

Genus UVIGERINA d'Orbigny, 1826

UVIGERINA BELLULA Bandy
Plate 7, fig. 7

Uvigerina auberiana d'Orbigny var. *laevis* GOËS, 1896, Bull. Harvard Mus. Comp. Zool., vol. 29, p. 51, pl. 4, figs. 71-74.

Uvigerina bellula BANDY, 1956, U.S. Geol. Survey Prof. Paper 274-G, p. 199, pl. 31, fig. 13.

Discussion: This species occurred at five stations in very low frequencies.

Genus SAGRINA d'Orbigny, 1839

SAGRINA PULCHELLA PRIMITIVA (Cushman)
Plate 7, fig. 8

Bolivina pulchella (d'Orbigny) var. *primitiva* CUSHMAN, 1930, Florida Geol. Surv., Bull. 4, p. 47, pl. 8, fig. 12.

Discussion: This species occurred at eight stations in low frequencies.

Genus SIPHOGENERINA Schlumberger, 1882

SIPHOGENERINA COSTATA Schlumberger
Plate 7, fig. 9

Siphogenerina costata SCHLUMBERGER, 1883, Feuille Jeunes Nat., no. 154, p. 118, text-fig. B.

Discussion: Single specimens were found at stations 8, 10, and 11.

Genus TRIFARINA Cushman, 1923

TRIFARINA BELLA (Phleger and Parker)
Plate 7, fig. 10

Angulogerina bella PHLEGER and PARKER, 1951, Geol. Soc. America, Mem. 46, pt. 2, p. 12, pl. 6, figs. 7, 8.

Trifarina bella (Phleger and Parker). BOCK, 1971, Miami Geol. Soc., Mem. 1, p. 49, pl. 17, fig. 13.

Discussion: Trifarina bella occurred in low frequencies at ten stations.

Superfamily DISCORBACEA Ehrenberg, 1838

Family DISCORBIDAE Ehrenberg, 1838

Subfamily DISCORBINAE Ehrenberg, 1838

Genus DISCORBIS Lamarck, 1804

PLATE 3

Figure Page

1,2. *Quinqueloculina lamarckiana* d'Orbigny.
Sample 9A, fig. 1, Side view, X85, fig. 2, Apertural view, X125 274

3,4. *Quinqueloculina poeyana* d'Orbigny.
Sample 9A, fig. 3, Side view, X75, fig. 4, Apertural view, X90 274

5,6. *Quinqueloculina polygona* d'Orbigny.
Sample 9A, fig. 5, Side view, X115, fig. 6, Apertural view, X225 274

7. *Quinqueloculina subpoeyana* Cushman.
Sample 6A, Side view, X170 275

8. *Pyrgo carinata* (d'Orbigny).
Sample 9A, Front view, X110 275

9. *Pyrgo subsphaerica* (d'Orbigny).
Sample 7B, Front view, X180 275

PLATE 3

DISCORBIS MIRA Cushman
Plate 7, figs. 11, 12

Discorbis mira CUSHMAN, 1922, Carnegie Inst. Washington, Publ. 311, p. 39, pl. 6, figs. 10, 11.

Discussion: This species occurred at 14 stations, and was present in frequencies ranging from rare to abundant.

DISCORBIS ROSEA (d'Orbigny)
Plate 8, figs. 1, 2

Rotalia rosea D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 272, no. 7.

Discorbis rosea (d'Orbigny). BOCK, 1971, Miami Geol. Soc., Mem. 1, p. 50, pl. 17, figs. 15, 16.

Discussion: This species occurred at eight stations in varying frequencies.

Genus NEOCONORBINA Hofker, 1951

NEOCONORBINA ORBICULARIS
(Terquem)

Rosalina orbicularis TERQUEM, 1876, Ess. Anim. Plage Dunkerque, pt. 2, p. 75, pl. 9, figs. 4a, b.

Neoconorbina orbicularis (Terquem). HOFKER, 1951, Arch. Neerlandaises Zool., vol. 8, pt. 4, p. 357.

Discussion: This species occurred at 11 stations in low to very low frequencies.

Genus ROSALINA d'Orbigny, 1826

ROSALINA CANDEIANA d'Orbigny
Plate 8, figs. 3, 4

Rosalina candeiana D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminiferes," p. 97, pl. 4, figs. 2-4.

Discussion: This species was present at 14 stations in low to very low frequencies.

ROSALINA FLORIDANA (Cushman)
Plate 8, figs. 5, 6

Discorbis floridanus CUSHMAN, 1922, Carnegie Inst. Washington, Publ. 311, p. 39, pl. 5, figs. 11, 12.

Rosalina floridana (Cushman). PARKER, 1954, Bull. Harvard Mus. Comp. Zool., vol. 111, no. 10, p. 524, pl. 8, figs. 19, 20.

Discussion: This species occurred at 13 stations in low to very low frequencies.

Genus STETSONIA Parker, 1954

STETSONIA MINUTA Parker
Plate 8, figs. 7, 8

Stetsonia minuta PARKER, 1954, Bull. Harvard Mus. Comp. Zool., vol 111, no. 10, p. 534, pl. 10, figs. 27-29.

Discussion: Single specimens were found at stations 6 and 14.

Genus TRETOMPHALUS Mobius, 1880

TRETOMPHALUS ATLANTICUS Cushman

Tretomphalus atlanticus CUSHMAN, 1934, Contr. Cushman Lab. Foram. Res., vol. 10, pt. 4, p. 86, pl. 11, fig. 3; pl. 12, fig. 7.

Discussion: This species occurred at nine stations but in very low frequencies.

Family SIPHONINIDAE Cushman, 1927
Genus SIPHONINA Reuss, 1850

SIPHONINA PULCHRA Cushman

Siphonina pulchra CUSHMAN, 1919, Carnegie Inst. Washington, Publ. 291, p. 42, pl. 14, figs. 7a-c.

Discussion: This species occurred at eight stations in low to very low frequencies.

Family ASTERIGERINIDAE d'Orbigny, 1839
Genus ASTERIGERINA d'Orbigny, 1839

PLATE 4

Figure — Page

1,2. *Triloculina bassensis* Parr.
Sample 8A, fig. 1, Side view, X115, fig. 2, Apertural view, X125 275

3,4. *Triloculina bermudezi* Acosta.
Sample 10B, fig. 3, Side view, X225, fig. 4, Apertural view, X430 275

5,6. *Triloculina fiterrei meningoi* Acosta.
Sample 1A, fig. 5, Side view, X180, fig. 6, Side view, X160 275

7. *Triloculina trigonula* (Lamarck).
Sample 8A, Front view, X160 276

8. *Miliolinella circularis* (Bornemann).
Sample 11A, Side view, X270 276

9. *Miliolinella fichteliana* (d'Orbigny).
Sample 9A, Side view, X135 276

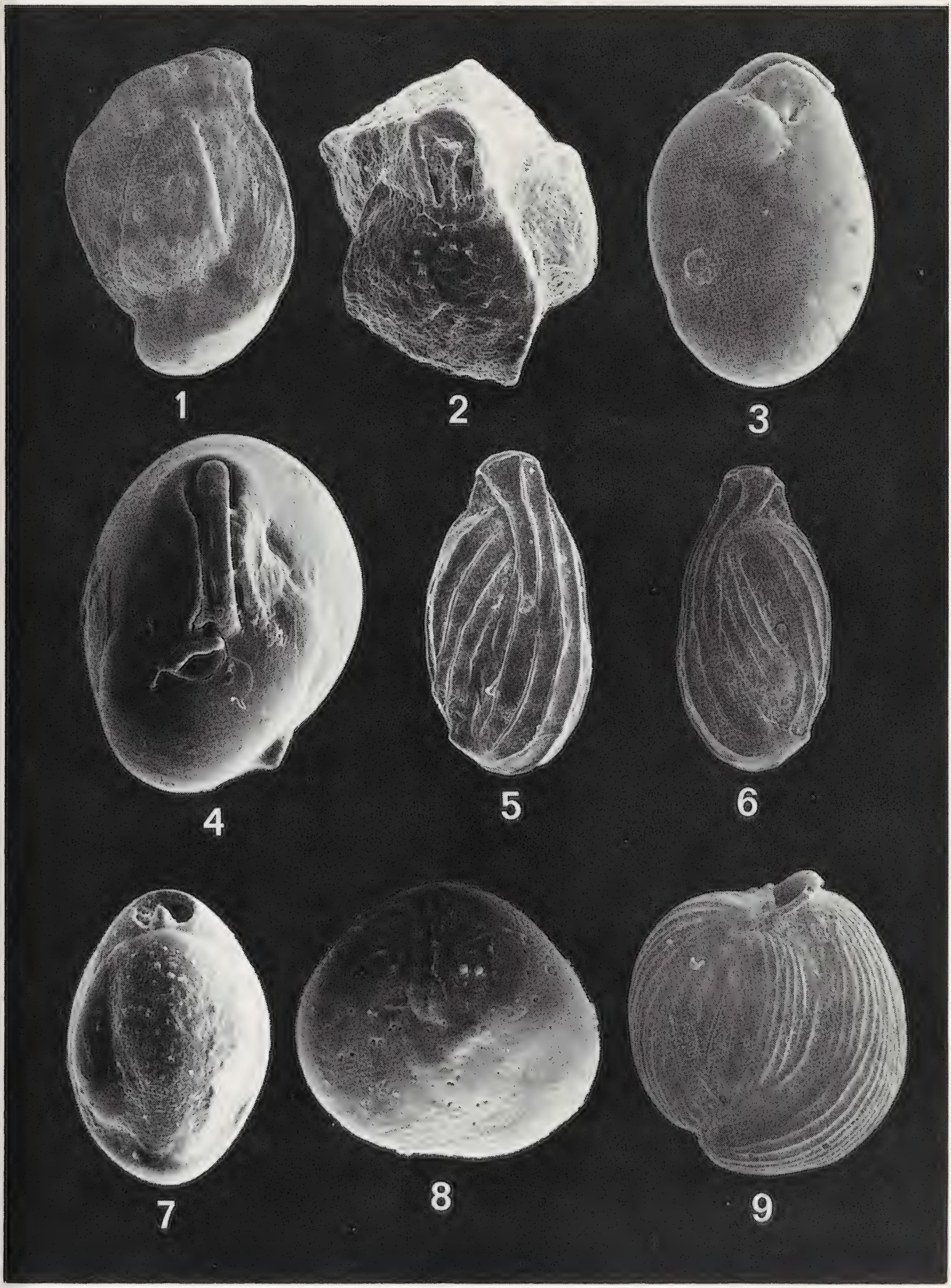

PLATE 4

ASTERIGERINA CARINATA d'Orbigny
Plate 8, fig. 9; Plate 9, fig. 1

Asterigerina carinata D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 118, pl. 5, fig. 25; pl. 6, figs. 1, 2.

Discussion: This species occurred at 14 stations in varying frequencies. It was common near the eastern margin of the bay and rare near the western margin; this probably is due to inshore transport.

Superfamily SPIRILLINACEA Reuss, 1862
Family SPIRILLINIDAE Reuss, 1862
Subfamily SPIRILLININAE Reuss, 1862
Genus SPIRILLINA Ehrenberg, 1843

SPIRILLINA DENTICULATA Brady

Spirillina limbata Brady var. *denticulata* BRADY, 1884, Rept. Voy. *Challenger,* Zool., vol. 9, p. 632, pl. 85, fig. 17.

Spirillina denticulata (Brady). PARR, 1929, B.A.N.Z. Ant. Res. Exped., ser. B, vol. 5, no. 6, p. 351.

Discussion: This species was very rare, with single specimens found only at stations 6 and 11.

SPIRILLINA VIVIPARA Ehrenberg
Plate 9, fig. 2

Spirillina vivipara EHRENBERG, 1843, Abhandl. k. Akad. Wiss. Berlin, Jahr. 1841, p. 422, pl. 3, sec. 7, fig. 41.

Discussion: This species occurred at eight stations in very low frequencies.

Superfamily ROTALIACEA Ehrenberg, 1839
Family ROTALIIDAE Ehrenberg, 1839
Subfamily ROTALIINAE Ehrenberg, 1839
Genus ROTALIA Lamarck, 1804

ROTALIA DUBIA (d'Orbigny)

Rotalina dubia D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 78, pl. 2, figs. 29, 30; pl. 3, fig. 1.

Discussion: A single specimen of this species was found in the "8A" sample.

Genus AMMONIA Brunnich, 1772

AMMONIA BECCARII PARKINSONIANA (d'Orbigny)
Plate 9, figs. 3, 4

Rosalina parkinsoniana D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 99, pl. 4, figs. 25-27.

Rotalia beccarii (Linné) var. *parkinsoniana* (d'Orbigny). PHLEGER and PARKER, 1951, Geol. Soc. America, Mem. 46, pt. 2, p. 23, pl. 12, figs. 6a, b.

PLATE 5

Figure — Page

1. *Miliolinella labiosa* (d'Orbigny).
Sample 11B, Side view, X180 276
2. *Hauerina bradyi* Cushman.
Sample 11B, Side view, X225 277
3. *Hauerina occidentalis* Cushman.
Sample 9A, Side view, X115 277
4. *Articulina mucronata* (d'Orbigny).
Sample 8A, Side view, X115 277
5. *Articulina multilocularis* Brady, Parker and Jones.
Sample 8B, Side view, X225 277
6. *Articulina sagra* d'Orbigny.
Sample 11B, Side view, X270 277
7. *Peneroplis bradyi* Cushman.
Sample 9A, Side view, X85 277
8. *Peneroplis carinatus* d'Orbigny.
Sample 9A, Side view, X135 277
9. *Peneroplis pertusus* (Forskal).
Sample 9A, Side view, X155 278

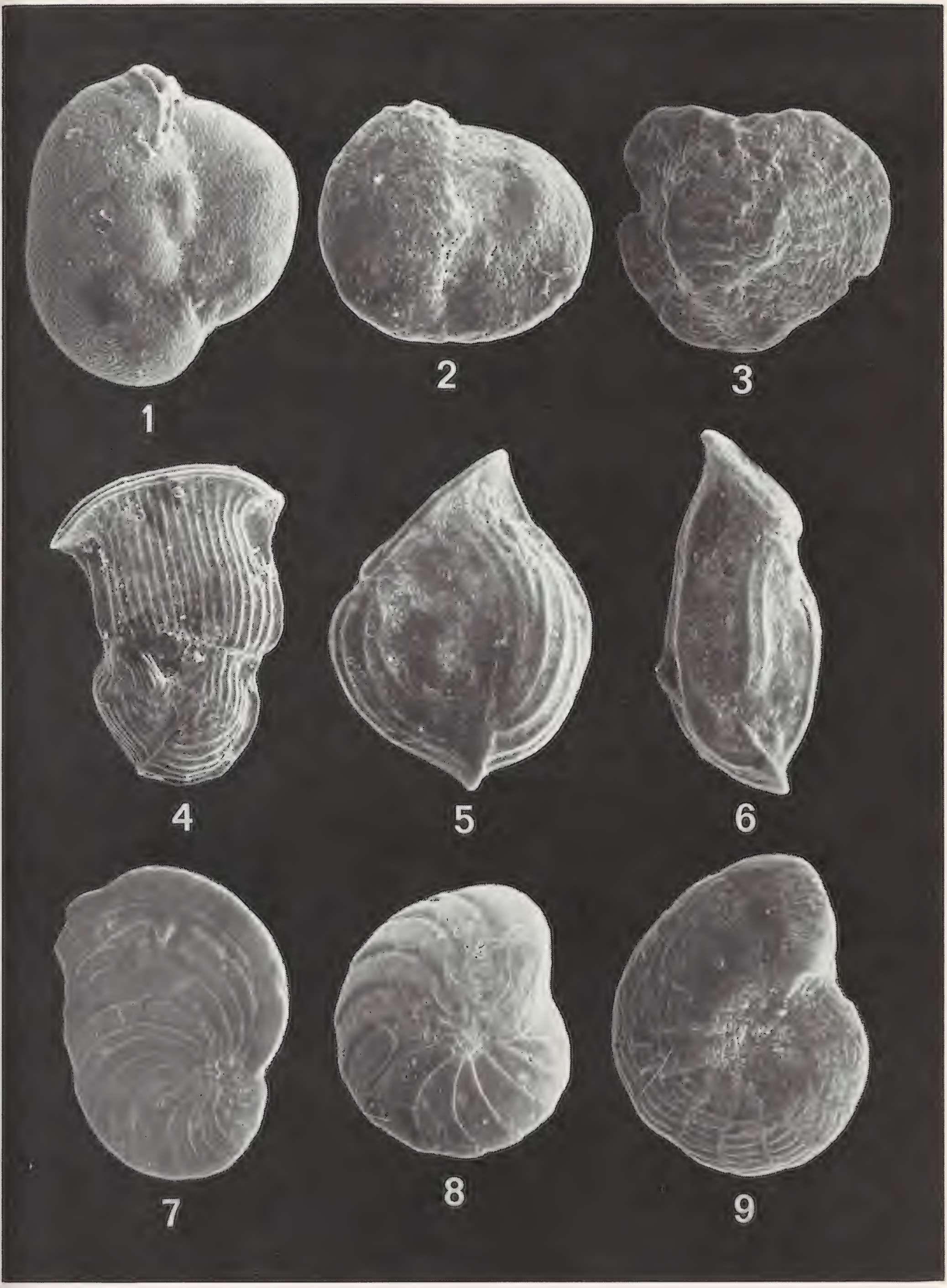

PLATE 5

Ammonia beccarii var. *parkinsoniana* (d'Orbigny). BOCK, 1971, Miami Geol. Soc., Mem. 1, p. 55, pl. 20, figs. 5, 6.

Discussion: This ubiquitous species was generally common or abundant. It accounted for nearly 50% of the "3A" sample, and occurred in only low frequencies near the eastern margin of the bay. It was the second-most common species observed in the total population, and was the fourth-most common species in the standing crop. It is an indicator of a stress environment (here brackish water).

AMMONIA BECCARII TEPIDA (Cushman)
Plate 9, figs. 5, 6

Rotalia beccarii (Linné) var. *tepida* CUSHMAN, 1926, Carnegie Inst. Washington, Publ. 344, p. 79, pl. 1.

Ammonia beccarii tepida (Cushman). WRIGHT and HAY, 1971, Miami Geol. Soc., Mem. 1, p. 150.

Discussion: This was by a very large margin, the most common species in the standing crop and the total population. It did not occur at station 12; but, it is a known indicator of a stress environment (here brackish water), and probably few were transported across the bay toward the more saline eastern bay margin. There was a great range in test size and many specimens were very worn, indicating the low amount of deposition and the effects of dredging and exposing older sediments. Several specimens probably were *Ammonia beccarii parkinsoniana,* but were not properly named due to accidental loss of the umbilical plug or to a very small plug not being observed.

Family ELPHIDIIDAE Galloway, 1933
Subfamily ELPHIDIINAE Galloway, 1933
Genus ELPHIDIUM Montfort, 1808

ELPHIDIUM ADVENUM (Cushman)
Plate 9, fig. 7

Polystomella subnodosa BRADY (*not* von Munster), 1884, Rept. Voy. *Challenger,* Zool., vol. 9, p. 734, pl. 110, fig. 1.

Polystomella advena CUSHMAN, 1922, Carnegie Inst. Washington, Publ. 311, p. 56, pl. 9, figs. 11, 12.

Elphidium advenum (Cushman). CUSHMAN, 1930, U.S. Natl. Mus., Bull. 104, pt. 7, p. 25, pl. 10, figs. 1, 2.

Discussion: This species was ubiquitous and occurred in low frequencies.

ELPHIDIUM GUNTERI GALVESTONENSE Kornfeld
Plate 9, figs. 8, 9

Elphidium gunteri Cole var. *galvestonensis* KORNFELD, 1931, Contr. Dept. Geol. Stanford Univ., vol. 1, no. 3, p. 87, pl. 15, figs. 1-3.

Discussion: This species was the fourth-most common in the total population, and

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PLATE 6

Figure Page

1. *Peneroplis proteus* d'Orbigny.
   Sample 9A, Side view, X85 278
2. *Spirolina acicularis* (Batsch).
   Sample 8A, Side view, X90 278
3. *Archaias angulatus* (Fichtel and Moll).
   Sample 9A, Side view, X40 278
4. *Sorites marginalis* (Lamarck).
   Sample 9A, Side view, X80 278
5. *Lagena laevis* (Montagu).
   Sample 6A, Side view, X270 279
6. *Guttulina laevis* de Pourtales.
   Sample 9A, Side view, X200 279
7. *Fissurina* cf. *F. lucida* (Williamson).
   Sample 3B, Oblique front-side view, X520 279
8. *Fissurina* sp. "A".
   Sample 10B, Front view, X315 280
9. *Buliminella elegantissima* (d'Orbigny).
   Sample 1B, Side view, X225 280

PLATE 6

was present at all stations. There is considerable variation in test size and shape.

ELPHIDIUM INCERTUM MEXICANUM Kornfeld

Elphidium incertum (Williamson) var. *mexicanum* KORNFELD, 1931, Contr. Dept. Geol. Stanford Univ., vol. 1, no. 3, p. 89, pl. 16, figs. 1, 2.

Discussion: This species occurred at six stations in low frequencies.

ELPHIDIUM SAGRUM (d'Orbigny)
Plate 9, fig. 10

Polystomella sagra D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 55, pl. 6, figs. 19, 20.

Elphidium sagrum (d'Orbigny). CUSHMAN, 1930, U.S. Natl. Mus., Bull. 104, pt. 7, p. 24, pl. 9, figs. 5, 6.

Discussion: This species occurred at nine stations, always in frequencies less than 1%.

Genus CRIBROELPHIDIUM Cushman and Bronnimann, 1948

CRIBROELPHIDIUM KUGLERI Cushman and Bronnimann
Plate 10, fig. 1

Cribroelphidium kugleri CUSHMAN and BRONNIMANN, 1948, Contr. Cushman Lab. Foram. Res., vol. 24, p. 18, pl. 4, fig. 4.

Discussion: This species was present at ten stations in low to very low frequencies.

CRIBROELPHIDIUM POEYANUM (d'Orbigny)
Plate 10, figs. 2, 3

Polystomella poeyana D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 55, pl. 6, figs. 25, 26.

Elphidium poeyanum (d'Orbigny). CUSHMAN, 1930, U.S. Natl. Mus., Bull. 104, pt. 7, p. 25, pl. 10, figs. 4, 5.

Cribroelphidium poeyanum (d'Orbigny). BOCK, 1971, Miami Geol. Soc., Mem. 1, p. 57, pl. 21, figs. 1, 2.

Discussion: This common to abundant species was absent only from station 12. In some samples frequency was near 1%, but frequency was most often near 10%; and it was third-most common in the total population.

Family NUMMULITIDAE de Blainville, 1825
Subfamily CYCLOCLYPEINAE Butschli, 1880
Genus HETEROSTEGINA d'Orbigny, 1826

PLATE 7

Figure Page

1. *Buliminella milletti* Cushman.
Sample 6B, Side view, X340 280
2. *Buliminoides williamsoniana* (Brady).
Sample 7B, Side view, X170 280
3. *Bolivinita rhomboidalis* (Millett).
Sample 10B, Side view, X270 282
4. *Bolivina lanceolata* Parker.
Sample 6A, Side view, X110 282
5. *Bolivina striatula* Cushman.
Sample 6A, Side view, X180 282
6. *Bulimina marginata* d'Orbigny.
Sample 6A, Side view, X475 282
7. *Uvigerina bellula* Bandy.
Sample 6B, Side view, X405 284
8. *Sagrina pulchella primitiva* (Cushman).
Sample 11A, Side view, X270 284
9. *Siphogenerina costata* Schlumberger.
Sample 10B, Side view, X110 284
10. *Trifarina bella* (Phleger and Parker).
Sample 8B, Side view, X290 284
11,12. *Discorbis mira* Cushman.
Sample 9A, fig. 11, Dorsal view, X110, fig. 12, Ventral view, X110 286

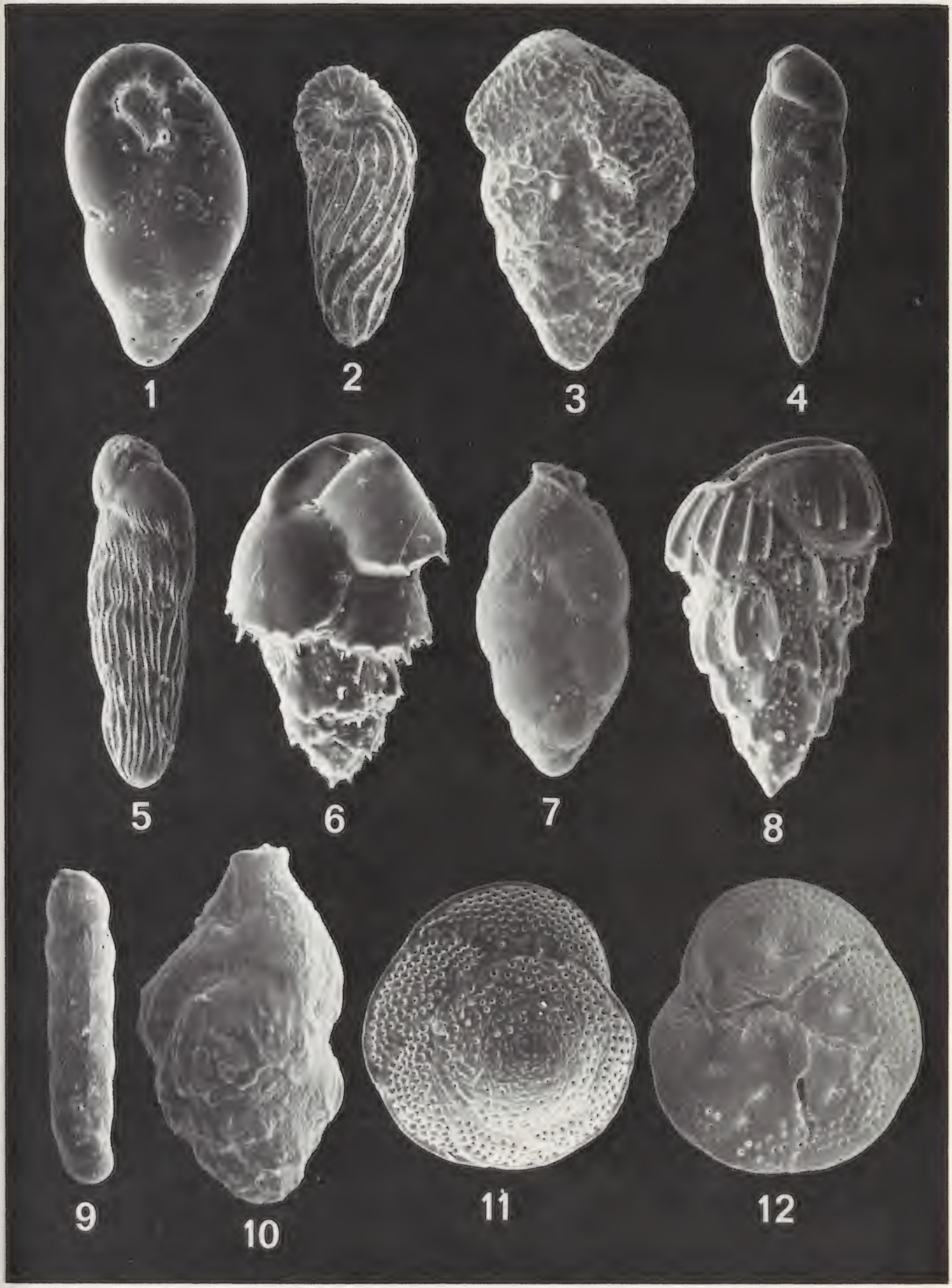

PLATE 7

HETEROSTEGINA DEPRESSA d'Orbigny

Heterostegina depressa D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 305, pl. 17, figs. 5-7.

Discussion: This species occurred at four stations and was rare.

Superfamily ORBITOIDACEA Schwager, 1876

Family AMPHISTEGINIDAE Cushman, 1927

Genus AMPHISTEGINA d'Orbigny, 1826

AMPHISTEGINA LESSONII d'Orbigny

Amphistegina lessonii D'ORBIGNY, 1826; Ann. Sci. Nat., vol. 7, p. 304, no. 3, pl. 17, figs. 1-4.

Discussion: This species was present at ten stations in low to medium frequencies.

Family CIBICIDIDAE Cushman, 1927

Subfamily CIBICIDINAE Cushman, 1927

Genus CIBICIDES Montfort, 1808

CIBICIDES DEPRIMUS Phleger and Parker

Cibicides deprimus PHLEGER and PARKER, 1951, Geol. Soc. America, Mem. 46, pt. 2, p. 29, pl. 15, figs. 16, 17.

Discussion: Two specimens of this species were found at station 7.

CIBICIDES FLORIDANA (Cushman)

Plate 10, figs. 4, 5

Truncatulina floridana CUSHMAN, 1918, U.S. Geol. Surv., Bull. 676, p. 62, pl. 19, figs. 2a-c.

Cibicides floridana (Cushman). CUSHMAN, 1930, Florida Geol. Surv., Bull. 4, p. 61, pl. 12, figs. 3a-c.

Discussion: This species occurred at 13 stations, in low to medium frequencies.

CIBICIDES REFULGENS Montfort

Cibicides refulgens MONTFORT, 1808, Conch. Syst., vol. 1, p. 122.

Discussion: This rare species occurred at three stations. The tests compare favorably with the Cushman figures in Bulletin 104 from the United States National Museum.

CIBICIDES SP.

Discussion: This species occurred at four stations in low frequencies. The specimens may be juveniles of another species.

Family PLANORBULINIDAE Schwager, 1877

Genus PLANORBULINA d'Orbigny, 1826

PLANORBULINA ACERVALIS Brady

Planorbulina acervalis BRADY, 1884, Rept. Voy. *Challenger,* Zool., vol. 9, p. 657, pl. 92, fig. 4.

Discussion: This species occurred at five stations in very low frequencies.

PLANORBULINA MEDITERRANENSIS d'Orbigny

Planorbulina mediterranensis D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 280, pl. 14, figs. 4-6.

Discussion: This species occurred at stations 1, 8, and 11, in very low frequencies.

Family CYMBALOPORIDAE Cushman, 1927

Genus CYMBALOPORETTA Cushman, 1928

CYMBALOPORETTA SQUAMMOSA (d'Orbigny)

Rotalia squammosa D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 272, no. 8.

Cymbaloporetta squammosa (d'Orbigny). CUSHMAN, 1928, Contr. Cushman Lab. Foram. Res., vol. 4, p. 7.

PLATE 8

Figure Page

1,2. *Discorbis rosea* (d'Orbigny).
Sample 9A, fig. 1, Dorsal view, X115, fig. 2, Ventral view, X115 286
3,4. *Rosalina candeiana* d'Orbigny.
Sample 7A, fig. 3, Dorsal view, X180, fig. 4, Ventral view, X190 286
5,6. *Rosalina floridana* (Cushman).
Sample 8A, fig. 5, Dorsal view, X160, fig. 6, Ventral view, X135 286
7,8. *Stetsonia minuta* Parker.
Sample 6A, fig. 7, Side view, X565, fig. 8, Apertural view, X585 286
9. *Asterigerina carinata* d'Orbigny.
Sample 9A, Dorsal view, X90 288

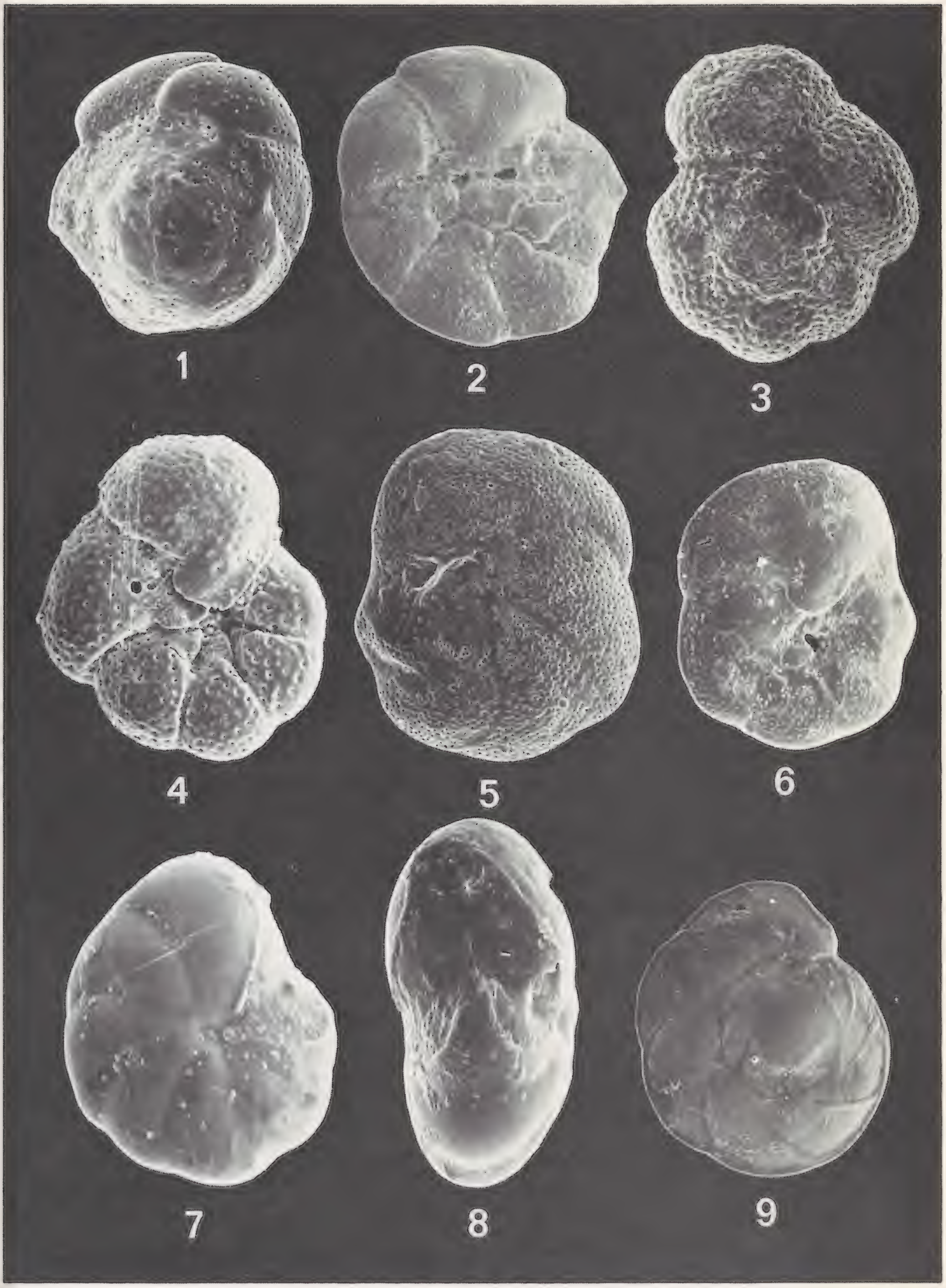

PLATE 8

Discussion: This species occurred at four stations in frequencies less than 1%.

Superfamily CASSIDULINACEA d'Orbigny, 1839
Family CAUCASINIDAE Bykova, 1959
Subfamily FURSENKOININAE Loeblich and Tappan, 1961
Genus FURSENKOINA Loeblich and Tappan, 1961

FURSENKOINA COMPRESSA (Bailey)
Plate 10, fig. 6

Bulimina compressa BAILEY, 1851, Smithsonian Contr., vol. 2, art. 3, p. 12, pl. 12, figs. 35-37.
Virgulina compressa (Bailey). CUSHMAN, 1922, U.S. Natl. Mus., Bull. 104, pt. 3, p. 116, pl. 24, figs. 2, 3.
Fursenkoina compressa (Bailey). BOCK, 1971, Miami Geol. Soc., Mem. 1, p. 62, pl. 23, fig. 7.

Discussion: This species occurred at 11 stations in low to fairly common frequencies.

FURSENKOINA MEXICANA (Cushman)
Plate 10, fig. 7

Virgulina mexicana CUSHMAN, 1922, U.S. Natl. Mus., Bull. 104, pt. 3, p. 120, pl. 23, fig. 8.
Fursenkoina mexicana (Cushman). BOCK, 1971, Miami Geol. Soc., Mem. 1, p. 62, pl. 23, fig. 8.

Discussion: This species occurred at four stations in very low frequencies.

FURSENKOINA PONTONI (Cushman)

Virgulina pontoni CUSHMAN, 1932, Contr. Cushman Lab. Foram. Res., vol. 8, pt. 1, p. 17, pl. 3, fig. 7.
Fursenkoina pontoni (Cushman). BOCK, 1971, Miami Geol. Soc., Mem. 1, p. 63, pl. 23, fig. 9.

Discussion: This species was present at five stations in very low frequencies.

Genus SIGMAVIRGULINA Loeblich and Tappan, 1957

SIGMAVIRGULINA TORTUOSA (Brady)
Plate 10, fig. 8

Bolivina tortuosa BRADY, 1881, Quart. Jour. Micr. Sci., vol. 21, p. 57.
Sigmavirgulina tortuosa (Brady). LOEBLICH and TAPPAN, 1957, U.S. Natl. Mus., Bull. 215, p. 227, pl. 73, figs. 1, 2.

Discussion: This species occurred at ten stations, always in frequencies less than 1%.

Family LOXOSTOMIDAE Loeblich and Tappan, 1962
Genus LOXOSTOMUM Ehrenberg, 1854

LOXOSTOMUM PORRECTUM (Brady)

Bolivina porrecta BRADY, 1881, Quart. Jour. Micr. Sci., vol. 21, p. 57.
Loxostomum porrectum (Brady). CUSHMAN, 1937, Cushman Lab. Foram. Res., Spec. Publ. 9, p. 190.

Discussion: This species was represented by a single specimen from the "6A" sample.

LOXOSTOMUM SP.

Discussion: Two specimens of this species were present in the "7A" sample.

Family CASSIDULINIDAE d'Orbigny 1839
Genus CASSIDULINA d'Orbigny, 1826

PLATE 9

Figure — Page

1. *Asterigerina carinata* d'Orbigny.
Sample 9A, Ventral view, X90 288
2. *Spirillina vivipara* Ehrenberg.
Sample 4B, Side view, X450 288
3,4. *Ammonia beccarii parkinsoniana* (d'Orbigny).
Sample 2A, fig. 3, Dorsal view, X155, fig. 4, Ventral view, X135 288
5,6. *Ammonia beccarii tepida* (Cushman).
Sample 2A, fig. 5, Dorsal view, X290, fig. 6, Ventral view, X225 290
7. *Elphidium advenum* (Cushman).
Sample 8B, Side view, X205 290
8,9. *Elphidium gunteri galvestonense* Kornfeld.
Sample 2A, fig. 8, Side view, X145, fig. 9, Apertural view, X135 290
10. *Elphidium sagrum* (d'Orbigny).
Sample 9A, Side view, X115 292

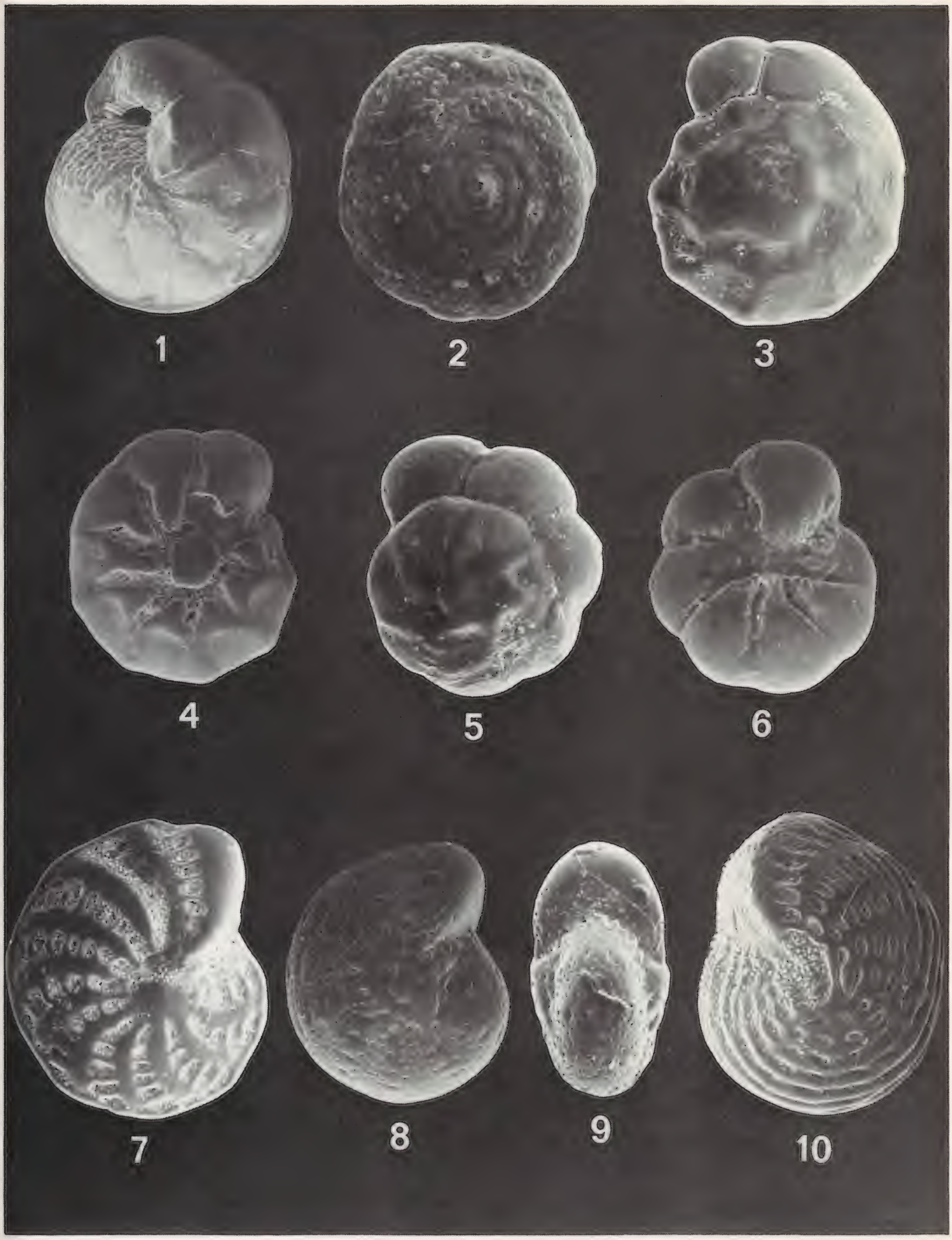

PLATE 9

CASSIDULINA SUBGLOBOSA Brady

Cassidulina subglobosa BRADY, 1881, Quart. Jour. Micr. Sci., vol. 21, p. 60.

Discussion: This species occurred at nine stations in low to very low frequencies.

Family NONIONIDAE Schultze, 1854
Subfamily NONIONINAE Schultze, 1854
Genus NONION Montfort, 1808

NONION BARLEEANUM (Williamson)

Nonionina barleeana WILLIAMSON, 1858, Rec. Foram. Great Britain, p. 32, pl. 3, figs. 68, 69.

Nonion barleeanum (Williamson). CUSHMAN, 1930, U.S. Natl. Mus., Bull. 104, p. 11, pl. 4, fig. 5.

Discussion: A single specimen occurred in the "9A" sample. The species normally occurs in deeper waters, and this specimen had been transported inshore.

NONION DEPRESSULUM MATAGORDANUM Kornfeld
Plate 10, fig. 9

Nonion depressula (Walker and Jacob), var. *matagordana* KORNFELD, 1931, Contr. Dept. Geol. Stanford Univ., vol. 1, no. 3, p. 87, pl. 13, figs. 2a, b.

Discussion: This species occurred at ten stations in low to very low frequencies.

Genus ASTRONONION Cushman and Edwards, 1937

ASTRONONION STELLIGERUM (d'Orbigny)

Nonionina stelligera D'ORBIGNY, 1839, *in* BARKER-WEBB and BERTHELOT, Hist. Nat. Iles Canaries, vol. 2, pt. 2, p. 128, pl. 3, figs. 1, 2.

Astrononion stelligerum (d'Orbigny). CUSHMAN and EDWARDS, 1937, Contr. Cushman Lab. Foram. Res., vol. 13, p. 31, pl. 3, figs. 7a, b.

Discussion: A single specimen was found in the "9B" sample.

Genus FLORILUS Montfort, 1808

FLORILUS GRATELOUPI (d'Orbigny)
Plate 10, fig. 10

Nonionina grateloupi D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 294, no. 19.

Nonion grateloupi (d'Orbigny). CUSHMAN, 1930, U.S. Natl. Mus., Bull. 104, pt. 7, p. 10, pl. 3, figs. 9-11; pl. 4, figs. 1-4.

Discussion: This species was present at 12 stations, always in frequencies less than 2%.

Genus NONIONELLA Cushman, 1926

NONIONELLA OPIMA Cushman

Nonionella opima CUSHMAN, 1947, Contr. Cushman Lab. Foram. Res., vol. 23, p. 90, pl. 20, figs. 1-3.

Discussion: This species was present at four stations in low to very low frequencies.

PLATE 10

Figure — Page

1. *Cribroelphidium kugleri* Cushman and Bronnimann.
Sample 6A, Side view, X225 292
2,3. *Cribroelphidium poeyanum* (d'Orbigny).
Sample 9A, fig. 2, Side view, X125, fig. 3, Apertural view, X115 292
4,5. *Cibicides floridana* (Cushman).
Sample 5B, fig. 4, Ventral view, X270, fig. 5, Dorsal view, X295 294
6. *Fursenkoina compressa* (Bailey).
Sample 6A, Side view, X180 296
7. *Fursenkoina mexicana* (Cushman).
Sample 6A, Side view, X225 296
8. *Sigmavirgulina tortuosa* (Brady).
Sample 11B, Side view, X225 296
9. *Nonion depressulum matagordanum* Kornfeld.
Sample 6A, Side view, X385 298
10. *Florilus grateloupi* (d'Orbigny).
Sample 6A, Side view, X155 298
11. Incertae sedis (unidentified yellow-colored attached form).
Sample 9A, Attached to a carbonate fragment 300

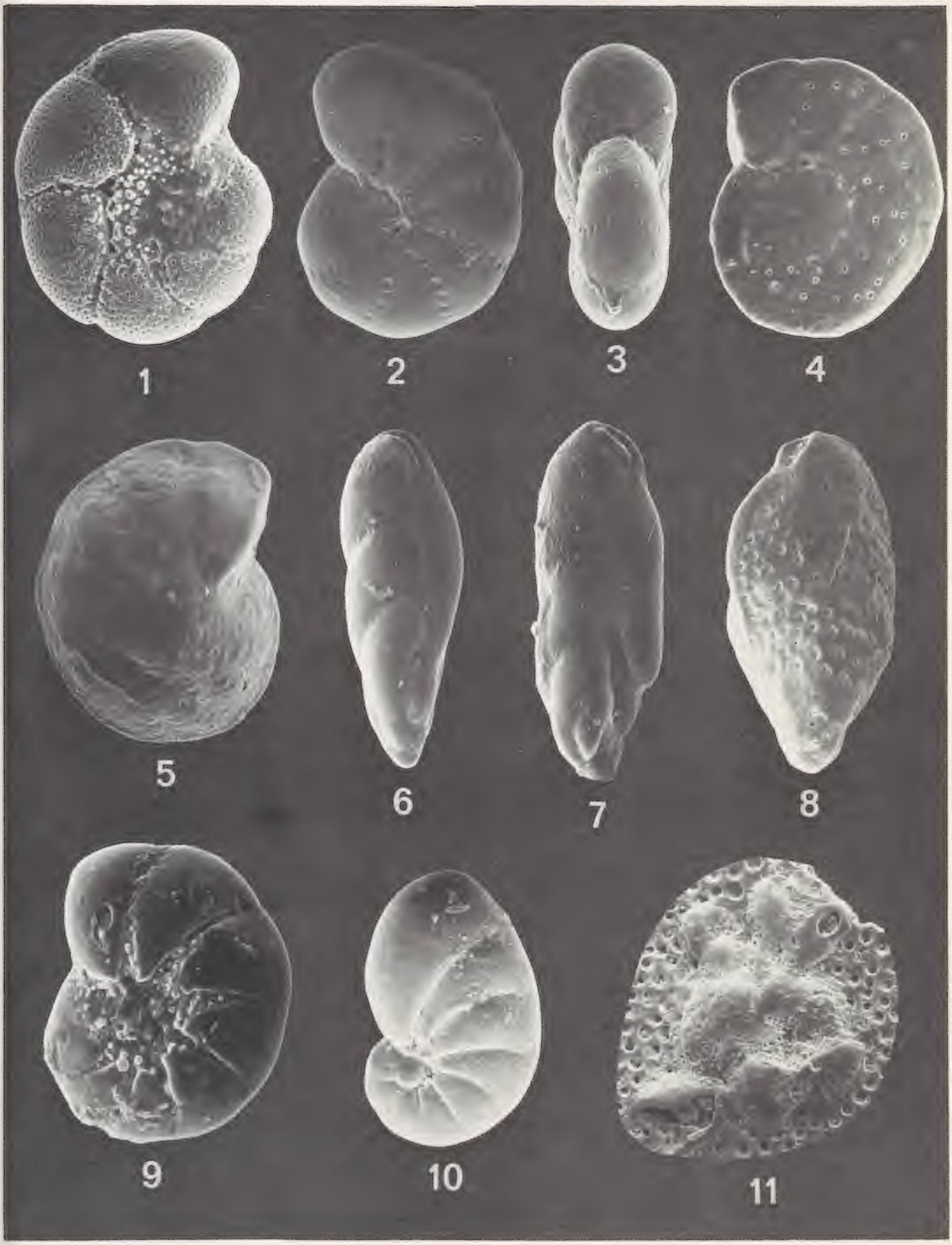

PLATE 10

Family ANOMALINIDAE Cushman, 1927
Subfamily ANOMALININAE Cushman, 1927
Genus HANZAWAIA Asano, 1944
HANZAWAIA STRATTONI (Applin)

Truncatulina americana Cushman var. *strattoni* APPLIN, 1925, Bull. Amer. Assoc. Petr. Geol., vol. 9, no. 1, p. 99, pl. 3, fig. 3.
Hanzawaia strattoni (Applin). BANDY, 1956, U.S. Geol. Surv. Prof. Paper 274-G, p. 195.

Discussion: This species was absent only from station 12. It was present in low frequencies near the western margin of the bay and was fairly common nearer the bay's eastern margin.

Suborder ROTALIINA Delage and Hérouard, 1896
Superfamily ROBERTINACEA Reuss, 1850
Family CERATOBULIMINIDAE Cushman, 1927
Subfamily CERATOBULIMININAE Cushman, 1927

Genus LAMARCKINA Berthelin, 1881
LAMARCKINA ATLANTICA Cushman

Lamarckina atlantica CUSHMAN, 1931, U.S. Natl. Mus., Bull. 104, pt. 8, p. 35, pl. 7, figs. 7a-c.

Discussion: Single specimens of this species were found at stations 7, 9, and 14.

INCERTAE SEDIS
Plate 10, fig. 11

Discussion: A single specimen of this attached species (yellow in color) was found at each of stations 9 and 13.

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November 19, 1975

A NEW HOLOCENE SPECIES OF *GLOBOROTALIA*

SCOTT W. SNYDER
EAST CAROLINA UNIVERSITY
GREENVILLE, NORTH CAROLINA

I. INTRODUCTION

Bottom samples from the Gulf of Mexico were obtained in order to study planktonic foraminiferal assemblages. The samples represent the uppermost sediments recovered during coring operations of the U.S.N.S. *Kane* (Cruise 939014) and the R. V. *Alaminos* (Traverse 64-A-9). A new species of *Globorotalia* Cushman, 1927, is present at six of the stations (Table 1).

The sediments at Station 87 of the *Kane* consist of clay. Surface lithology from cores recovered by the *Alaminos* could not be observed because the samples were washed through sieves prior to receipt.

II. ACKNOWLEDGMENTS

The writer wishes to thank Dr. Hubert C. Skinner, Department of Geology, Tulane University, who obtained materials recovered by the R. V. *Alaminos.* Dr. Herbert C. Eppert, Jr. of the U.S. Naval Oceanographic Office supplied materials recovered during Cruise 939014 of the U.S.N.S. *Kane.* Dr. W. H. Akers of Chevron Oil Company has assisted in both taxonomic considerations and technical aspects of this study. Paul Koeppel of Chevron Oil Company photographed the specimens.

III. METHODS

All materials coarser than 0.074 mm (No. 200, U. S. Standard Sieve) were examined for planktonic foraminiferal specimens. Specimens referable to the species described herein were picked and mounted on slides.

Photographs were taken with the Cambridge scanning electron microscope at Chevron Oil Company, New Orleans, Louisiana.

Type specimens are deposited at the United States National Museum.

IV. SYSTEMATIC DESCRIPTIONS

GLOBOROTALIA AKERSI Snyder, n. sp.

Plate 1, figs. 1-6; Plate 2, figs. 1-5

Holotype: USNM 216182; maximum diameter, 0.87 mm; *Kane* Station 87.

Paratypes: USNM 216181; maximum diameter, 0.60 mm; *Alaminos* Station 27E; USNM 216183; maximum diameter, 0.61 mm; *Alaminos* Station 27E; USNM 216184; maximum diameter, 1.06 mm; *Alaminos* Station 24E; USNM 216185; maximum diameter, 0.79 mm; *Alaminos* Station 27E (not figured).

Description: The test is a large, moderately low trochospire with five to six and one-half gradually enlarging chambers in the final whorl. Coiling may be either dextral or sinistral, but the latter is dominant. The test is slightly to moderately biconvex, with the umbilical side in some specimens more strongly inflated. The outline in plan view is subquadrate, elliptical, or nearly round and the periphery is lobulate and carinate. Sutures are radial to slightly curved and depressed on the umbilical side, oblique to curved and nearly flush to limbate on the spiral side. The final chamber extends across the umbilicus to attach to earlier formed chambers of the final whorl. This chamber may continue in the same plane as earlier chambers of the final whorl or be markedly angled to that plane. It may be larger or smaller than the penultimate chamber but always extends across the umbilicus to obscure the primary aperture. The aperture lies along the basal margin of the modified final chamber and is either small and slit-like or appears as a series of small infralaminal openings.

Discussion: Globorotalia akersi has close morphologic affinities with *Globorotalia menardii* and *Globorotalia ungulata.* Specimens with only slight biconvexity, a nearly round equatorial profile, and sutures that are limbate on the spiral side of the test (pl. 1,

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PLATE 1

Figures

1. Paratype, USNM 216181, umbilical view, X 102.
2. Paratype, USNM 216181, spiral view, X 102.
3. Paratype, USNM 216181, edge view, X 102.
4. Holotype, USNM 216182, umbilical view, X 91.
5. Holotype, USNM 216182, spiral view, X 91.
6. Holotype, USNM 216182, edge view, X 91.

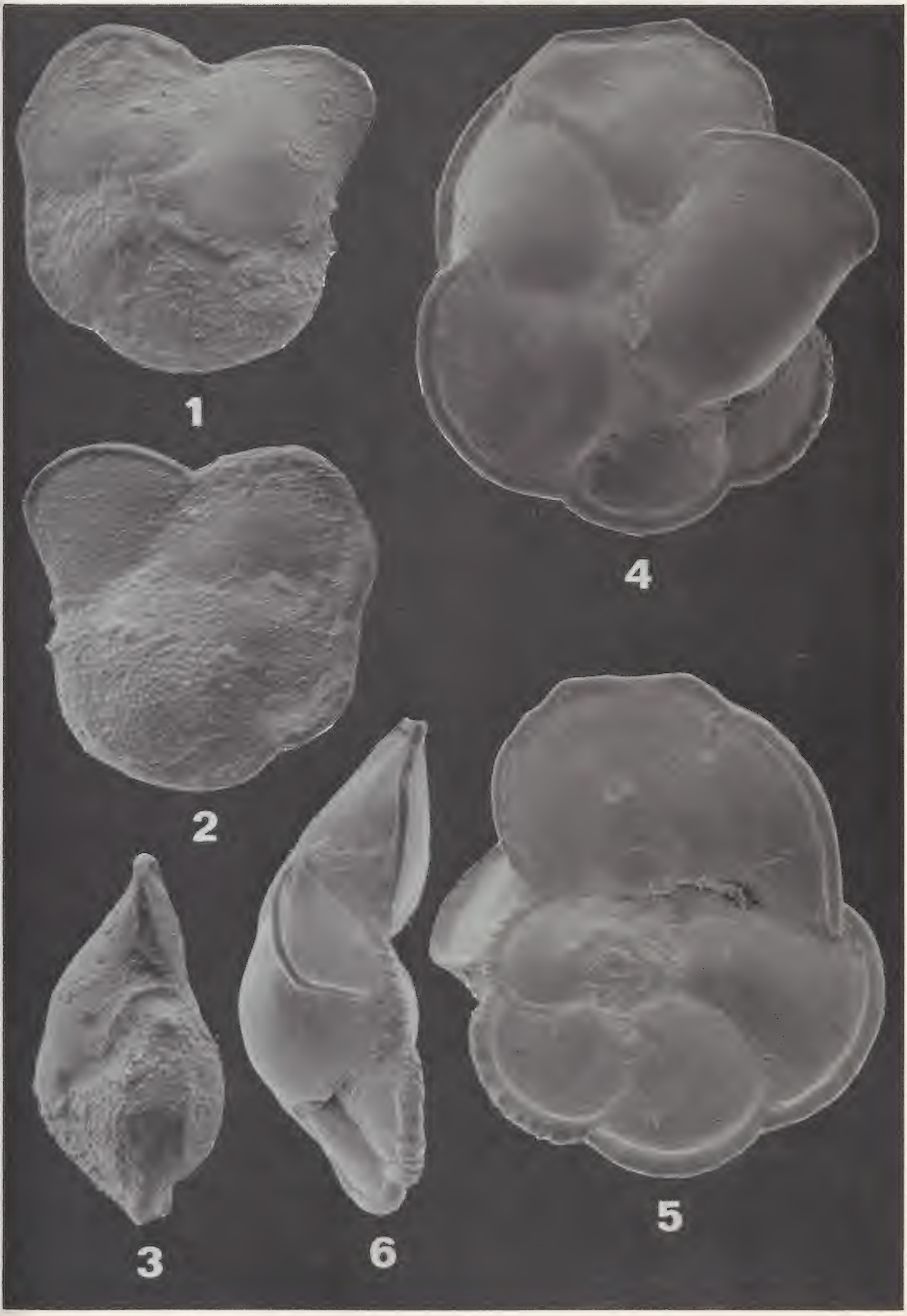

PLATE 1

TABLE 1. COLLECTING STATIONS

Station Number	Source	Location	Water Depth (meters)
87	Kane	23°38'N, 91°30'W	3685
13E	Alaminos	24°17'N, 91°07'W	2010
24E	Alaminos	22°50'N, 90°42'W	492
26E	Alaminos	22°56'N, 90°52'W	620
27E	Alaminos	23°01'N, 90°50'W	1995
30E	Alaminos	23°37'N, 91°16'W	1969

figs. 4-6; pl. 2, figs. 1-3) resemble *Globorotalia menardii.* This morphologic variant is numerically dominant. Specimens with more highly inflated chambers, an elliptical to subquadrate equatorial profile, and nearly flush to slighly limbate sutures on the spiral side of the test (pl. 1, figs. 1-3) resemble *Globorotalia ungulata.*

It is possible that the specimens included within *Globorotalia akersi* represent two lines of similar evolutionary development, one stemming from *Globorotalia menardii* and the other from *Globorotalia ungulata.* However, because of the scarcity of specimens (only 20 have been found) all variants have been assigned to a single species. About 20% of the specimens are highly contorted (pl. 2, figs. 4-5). Given the scarcity of specimens, any statement as to the significance of this would be purely speculative.

Globorotalia akersi can be distinguished from *Globorotalia menardii* and *Globorotalia ungulata* because its final chamber extends across the umbilicus and gives rise to a small, slit-like aperture or to multiple infralaminal apertures. Both *Globorotalia menardii* and *Globorotalia ungulata* lack the modified final chamber and have a large, high arched, umbilical-extraumbilical aperture.

Globorotalia akersi is encountered only in a small area of the south-central portion of the Gulf of Mexico. Within this restricted range it comprises less than 1% of the planktonic foraminiferal assemblage.

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PLATE 2

Figures

1. Paratype, USNM 216183, umbilical view, X 99.
2. Paratype, USNM 216183, spiral view, X 99.
3. Paratype, USNM 216183, edge view, X 99.
4. Paratype, USNM 216184, contorted variant, umbilical view, X 82.
5. Paratype, USNM 216184, contorted variant, spiral view, X 82.

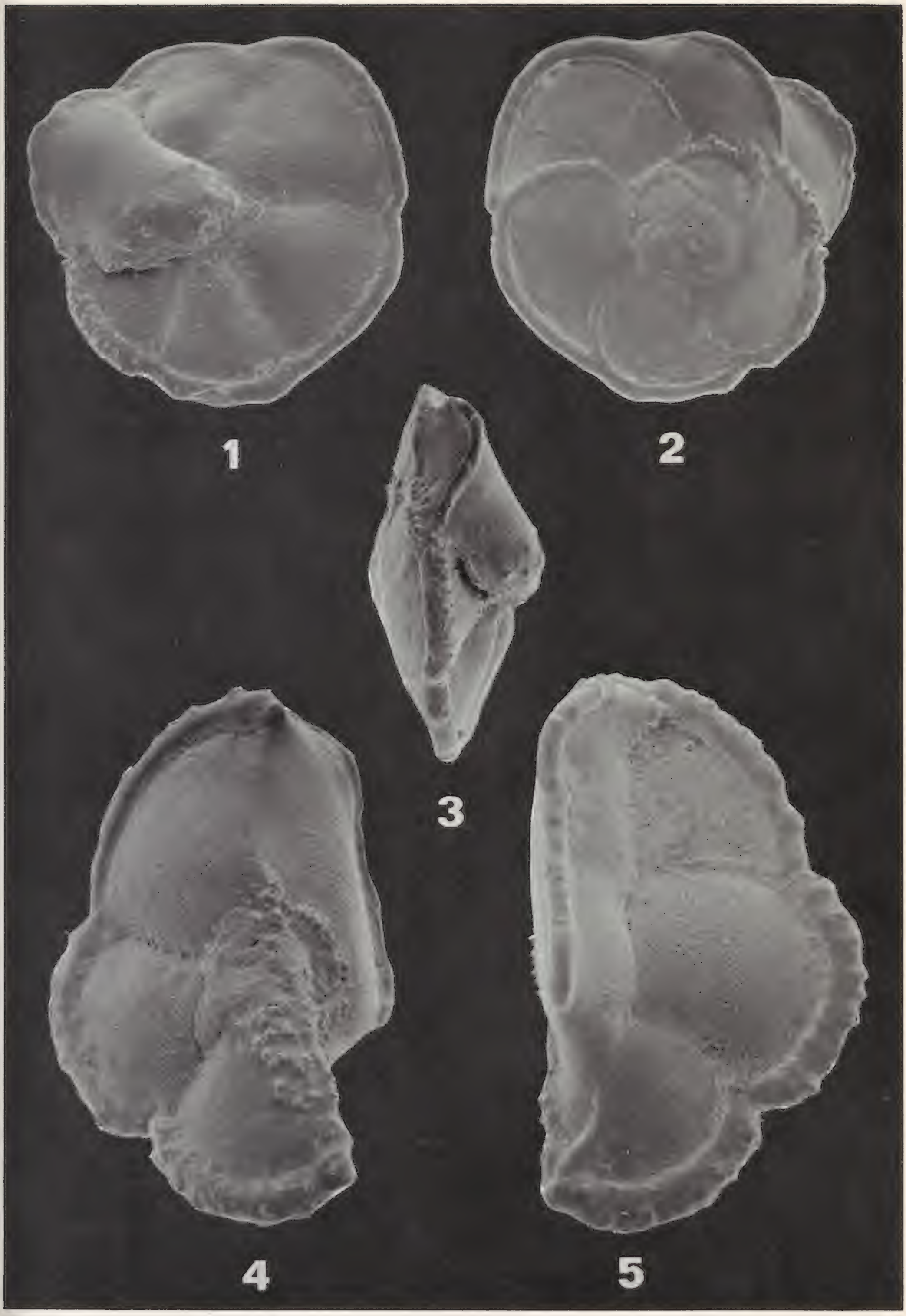

PLATE 2

PALEONTOLOGICAL NOTES

STATUS OF THE CRETACEOUS PLANKTONIC FORAMINIFERAL GENERA *ANATICINELLA* AND *PSEUDOTICINELLA*

DREW HAMAN
EXPLORATION DEPT., CHEVRON OIL COMPANY, NEW ORLEANS

The planktonic foraminiferal genus *Pseudoticinella* was recently described by Longoria (1973) with *Globorotalia? multiloculata* Morrow, 1934, selected as type species. Prior to the designation of this taxon as *Pseudoticinella multiloculata* (Morrow) by Longoria in 1973 the species has been assigned to other genera by various authors. Some of these generic assignments were to *Globorotalia?* by Morrow (1934); *Rugoglobigerina,* by Bermudez (1952); *Thalmanninella* by Bronnimann and Brown (1955); and *Ticinella* by Eicher and Worstell (1970). Longoria (1973) stated that *Pseudoticinella* could be differentiated generically from *Ticinella* by possessing an imperforate peripheral band and an umbilical cover plate, and from *Thalmanninella* by lacking a keel.

Globorotalia? multiloculata had also been selected as the type species for the genus *Anaticinella* by Eicher (1972). The genera *Anaticinella* and *Pseudoticinella* are congeneric, and *Anaticinella* is determined as the valid taxon on the basis of priority. As a result of this determination the new species *Pseudoticinella planoconvexa* is transferred to the genus *Anaticinella.*

Thalmanninella has been established as a junior synonym of *Rotalipora* by Loeblich and Tappan (1964). Eicher (1972) noted that *Anaticinella* could be separated from *Rotalipora* by the presence or absence of a keel, but he further noted the morphologic similarities between *Anaticinella* and *Ticinella.* He justified the erection of his new genus both on a morphologic basis with regard to *Rotalipora (=Thalmanninella)* and on phyletic distinctness with regard to *Ticinella.*

Ticinella is limited to the Albian and Aptian. This genus gave rise to *Rotalipora* in the Albian, which in turn gave rise to *Anaticinella* in the Cenomanian. Eicher (1972) suggested that *A. multiloculata* could not be a late Cenomanian extension of the *Ticinella* lineage, as no representatives of either of these genera occur in the stratigraphic interval between the late Albian and late Cenomanian.

The stratigraphic range of *Anaticinella* is questionable. Eicher (1972) regarded this genus basically as a late Cenomanian form, although he indicated that it ranges into the early Turonian. Longoria (1973) recorded *Pseudoticinella* (now *=Anaticinella*) from strata he regarded as early Turonian in age. This determination was made by Longoria on material corresponding to locality "D-2" of the First Interamerican Micropaleontological Colloquium; Dallas, Texas, 1970. Locality "D-2", Britton Member, Eagle Ford Formation, is regarded as late Cenomanian in age, the *Rotalipora* Assemblage Zone, *R. cushmani-greenhornensis* subzone. (See p. A28, IMC 1 Guidebook, Powell, 1970). The age range Longoria assigned to his genus, however, was late Cenomanian to early Turonian.

Microfaunal evidence for the placement of the Turonian-Cenomanian boundary has been fully discussed with reference to the Eagle Ford Group by Douglas and Sliter (1966) and need not be repeated here. It is sufficient to state that the genus *Anaticinella* has a stratigraphic range of late Cenomanian to early Turonian.

Anaticinella is sufficiently distinct both morphologically and phyletically to justify the erection of a new genus. *Pseudoticinella* does not fulfil these requirements and must be regarded as a junior synonym of *Anaticinella.*

ACKNOWLEDGMENTS

The writer is indebted to F.B. Bourgeois and B.R. Wilhoit for helpful discussions; to Dr. W. H. Akers for reading an earlier draft of the manuscript; to P. Haman for technical assistance and the Chevron Oil Company for publication permission.

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REVIEWS

HUBERT C. SKINNER
TULANE UNIVERSITY

AN ATLAS OF BRITISH RECENT FORAMINIFERIDS, by John W. Murray. Published by American Elsevier Publishing Company, Inc., New York, 1971, xii + 244 pp., illus., $22.50

This handsome book illustrates 129 foraminiferids from the seas around the British Isles. Each species is depicted in several views with scanning electron photomicrographs at magnifications from 6000X to 20,000X, displaying details of the aperture and the texture of the walls in addition to the external morphology of the test. The brief text includes information on the geographical distribution of the species and lists of the forms which characterize each environmental habitat. Relict sediments and anomalous records are discussed. Each plate is accompanied by a short description of the species, notes on important nomenclatorial changes, and reported distributions in western Europe.

MANUAL OF PLANKTONIC FORAMINIFERA, by J. A. Postuma. Published by Elsevier Publishing Company, Amsterdam, London, New York, 1971, vii + 420 pp., illus., $29.00

This attractive volume presents an atlas of 160 species of planktonic foraminiferids selected by the author for their importance in correlation of Mesozoic and Cenozoic strata. The quarto format permits three (or four) large-scale photomicrographs of each species to be arranged in a vertical column with the corresponding view illustrated by an excellent artist's drawing alongside each photograph. A cross-sectional drawing of the species is added at the bottom of each plate to assist in recognition of these forms in thin-sections of limestones. Three folding range-charts add to the usefulness of this well-executed work. It deserves a place on the shelves of all active micropaleontologists.

NEW NAME FOR A WESTERN ATLANTIC MARGINELLID

BARRY ROTH
CALIFORNIA ACADEMY OF SCIENCES
SAN FRANCISCO, CALIFORNIA

A recent publication (Kaicher, 1973) has illustrated for the first time several of the small marginellid species described by Dall (1927) from dredgings in deep water off Georgia and Florida. The name of one of the figured species is a primary homonym, preoccupied by Dall's own use of the same name for another taxon. Because the figure is this popularly oriented work is likely to lead to recognition of the species in museum and perhaps in private collections, this seems an appropriate time to provide a replacement for the preoccupied name.

VOLVARINA DISCORS Roth, nom. nov.

Marginella [Marginella] inepta DALL, 1927, U.S. Natl. Mus., Proc., v. 70, art. 18, no. 2667, pp. 4, 45.

Volvarina inepta (Dall). KAICHER, 1973, Card Cat. World-wide Shells, 1, Marginellidae, fig. 47 (holotype).

Not *Marginella bella* Conrad, var. *inepta* DALL. 1890, Wagner Free Inst. Sci., Trans., v. 3, part 1, p. 53, pl. 4, fig. 8d; DALL, 1915, U.S. Natl. Mus., Bull. 90, p. 53, pl. 15, fig. 2 (as *Marginella inepta* Dall).

Type locality: Recent, off Georgia and Fernandina [Florida], in 440 and 294 fathoms.

Holotype, USNM 107974.

Dall's name of 1927 is considered preoccupied by his earlier use of the same epithet at the varietal rank in accordance with Article 17 of the International Code of Zoological Nomenclature. Roth and Clover (1973, p. 208) discuss the application of the Code in comparable cases.

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November 19, 1975

REVIEW

HUBERT C. SKINNER
TULANE UNIVERSITY

THE GEOLOGICAL STRUCTURE OF NEW ZEALAND, by Jacobus T. Kingma. Published by John Wiley & Sons, New York, London, Sydney, Toronto, 1974, xvii + 407 pp., illus., $60.00

This is a volume of the *Regional Geology Series,* edited by L. U. de Sitter. It is a well-illustrated practical account of the geological history of the New Zealand area, including the sedimentary processes, tectonic unrest and mountain building, and crustal decay. This work provides a comprehensive modern account of the geology of New Zealand and its important role in the geological history of the Southwest Pacific which fills a significant gap in the currently available literature.

Introductory chapters deal with the broad aspects of New Zealand geology and geosynclinal history, the origin of New Zealand and its solitary position in the South Pacific Ocean basin, and the gravity field of the area. Subsequent chapters review the geology in a logical stratigraphic order. Concluding chapters are concerned with igneous masses, geosynclinal sedimentaries, orogenic and diastrophic movements, and notes on the reconstruction of Gondwana in the South Pacific region.

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SERIES	MIDDLE EOCENE						MIDDLE EOCENE				M. EOCENE		MIDDLE EOCENE				MIDDLE EOCENE			MIDDLE EOCENE						MIDDLE EOCENE			MIDDLE EOCENE		
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TENUIS	▲	▲	▬	▲			▲		▬	▲	●	●			●		●			●	●	●	●	●	▲	●	●	●	●	●	
RHABDOLITHES GLADIUS											●	●					●								●						
RUDIS						●		●			●					●	●			●	●	●		●	●	●	●	●			●
BRAARUDOSPHAERACEAE																															
BRAARUDOSPHAERA BIGELOWI	●				●							●		●	●	●	●		●	●				●	●	●	●	●		●	
DISCULA				●							●					●					●				●	●	●	●		●	●
MICRANTHOLITHUS FLOS				●									●	●		●	●		●					●				●		●	●
ORNATUS					●								●								●			●					●	●	
PROCERUS															●		●			●				●					●	●	
PEMMA ANGULATUM			●	●																				●							
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SPHENOLITHACEAE																															
SPHENOLITHUS FURCATOLITHOIDES																			●		●	●			●						●
MORIFORMIS	●	●	●	●	▲	▲		●		●	●	●	●	▲	●	▲	●	●	●	●	▲	▲	▲	●	▲	●	▲	●	▲	●	▲
OBTUSUS															●		●	●													
RADIANS	●		●			●				▲					●			●	●					●			●		▲	●	●
LITHOSTROMATIONIDAE																															
TROCHOASTER SIMPLEX		●		●	●	●		●		●		●					●											●			
RADIATUS																															
DISCOASTERACEAE																															
DISCOASTER ASTER															●	●			●						●	●					
BARBADIENSIS									●		●		●	●	●	●	●	▲	●		●	●	●	●	●	●	▲	▲	●	●	●
BINODOSUS BINODOSUS			●		▲	●									●			●	●								●				
BINODOSUS HIRUNDINUS									●														●								
DEFLANDREI		●	●						●					●			▬	●						●		●	●	●		●	
DIASTYPUS															●	▲															
DISTINCTUS			●		●			●	●			●				●			●	●	●		●	●				●	●		
ELEGANS	▲	▬	▲	●	✱	●	●	●	▲	●	●	●				●			●	●	●	●		●		●					
LENTICULARIS							●	●	●		●	●						●	●						●		●				
LODOENSIS																			●						●						
MIRUS												●			●																
SAIPANENSIS				●										●	●		●	●	●				●	●	●	●		●	●	●	●
STELLA		●										●				●	●		●						●			●	●	●	
SUBLODOENSIS															●	●		●										●			
TANI NODIFER								●										●			●						●		●	●	
TUMESCENS					●										●										●					●	
TRIANGULARIS																												●			
WOODRINGI																								●		●		●			
DISCOASTEROIDES KUEPPERI	●																												●		
MARTHASTERITES FURCATUS					●	●	●	●			●																				
ZYGODISCACEAE																															
CHIPHRAGMALITHUS CALATHUS		●	●																											●	
NEOCOCCOLITHES DUBIUS	●		●	●			●	●	●					●	●	●	●						●	●		●			●	●	●
ZYGOSPHAERACEAE																															
ZYGRHABLITHUS BIJUGATUS	▲	●	●	●			▲	▬	▲	▲	●	▲	▬	✱	✱	▬	✱	✱	✱	▬	▬	✱	▬	✱	▬	▬	▬	▬	✱	✱	▬

TABLE 1

*SAMPLE DEPTH IN FEET

Vol. 11, No. 2, NOTES ON *CHICOREUS* FROM THE CENOZOIC OF THE WESTERN ATLANTIC REGION, WITH THE DESCRIPTION OF NEW SPECIES, by Emily H. Vokes; NOTES ON THE FAUNA OF THE CHIPOLA FORMATION—XV, ON THE OCCURRENCE OF *"RANELLA" POPPELACKI* HÖRNES, A GASTROPOD OF UNCERTAIN AFFINITIES, and XVI, ON THE COLOR PATTERN OF *GLOBULARIA FISCHERI,* by Emily H. Vokes; XVII, ON THE PRESENCE OF *CLEMENTIA (EGESTA) GRAYI* DALL, by Harold E. Vokes; A NEW CARIBBEAN SPECIES OF THE GENUS *NERITOPSIS,* by Robert C. Hoerle; A NEW PLICATULID BIVALVE FROM THE LATE CENOZOIC OF SOUTHERN FLORIDA, by Graig D. Shack and David Nicol; THE PLIOCENE HORSE *NANNIPPUS MINOR* IN GEORGIA: GEOLOGIC IMPLICATIONS, by M.R. Voorhies; *CERATOLITHUS ACUTUS* GARTNER AND BUKRY, N. SP. AND *CERATOLITHUS AMPLIFICATUS* BUKRY AND PERCIVAL—NOMENCLATURAL CLARIFICATION, by Stefan Gartner and David Bukry; AGE OF THE PINECREST BEDS, SOUTH FLORIDA, by W.H. Akers: pp. 81-120 (July 31, 1974) $3.50

Vol. 11, No. 3, CENOZOIC MURICIDAE OF THE WESTERN ATLANTIC REGION. PART VI—*ASPELLA* AND *DERMOMUREX,* by Emily H. Vokes; NOTES ON THE FAUNA OF THE CHIPOLA FORMATION—XVIII, SOME NEW OR OTHERWISE INTERESTING MEMBERS OF THE CALYPTRAEIDAE, by Emily H. Vokes; A NEW SPECIES OF *ENDOPACHYS* FROM THE MIOCENE OF FLORIDA, by John W. Wells; *NERITOPSIS ATLANTICA* SARASUA, A PRIOR NAME FOR *NERITOPSIS FINLAYI* HOERLE, by Robert C. Hoerle: pp. 121-176 (February 5, 1975) $3.50

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Ammobaculites agglutinans	0.9	0.8		0.2		0.2				(1)								(1)				*				(1)		*														0.2		0.2										
Ammonia beccarii parkinsoniana	10.5	13.7	6.3	6.6	2.4	30.2	3.6	11.0	13.3	49.9	9.3	14.2		12.5	13.3	7.9		3.1		17.9	3.5	3.1		2.1		4.6		2.2	8.3	5.9		9.8		1.3		4.0	13.2	4.6		2.5	7.1	1.3		1.9		1.6		1.9		1.0	12.5	1.1
Ammonia beccarii tepida	14.8	34.6	39.2	47.7	16.7	39.0	28.6	40.7	30.6	20.7	55.8	43.5	64.7	32.4	46.7	27.1	42.9	10.7	75.0	8.7	41.7	25.1	63.6	14.7	4.3	5.5	58.3	9.2	18.8	11.2	30.0	7.4	0.3	50.0	2.2	29.7	17.7	14.3	9.8	28.6	4.7	66.7	5.1			12.5	1.9	5.9	1.3	62.5	12.9
Ammotium salsum				(1)																	*	(1)															1.1	0.3																
Amphistegina lessonii																	1.3		4.5			0.3	0.2		2.0		1.2		1.0		1.5		3.1		1.9		0.3		0.7		1.0		1.7				1.9		4.5		1.1	
Archaias angulatus		(2)		*																													7.8		4.3				*		(1)		1.0	8.7	27.3		1.9		0.3	
Articulina antillarum										(1)				0.2				0.3		0.3		(1)																															
Articulina lineata																										(1)																									0.3	
Articulina mayori																												0.2																								
Articulina mucronata						(1)									0.2		(1)	0.6				*				0.9				1.7		0.7	1.6	2.2	0.2	1.0	1.1	1.5	1.0	0.6	3.5	0.9
Articulina multilocularis						*																				(1)						0.2																		
Articulina sagra															0.4	1.6	0.6	0.4	0.5	1.7				1.3		0.7							0.6	0.9	0.2	0.5	3.6	2.7	0.5	1.0	2.9	1.1
Asterigerina carinata				0.2		0.3								0.2		*		1.2		3.8		(1)		*		3.8		1.6		1.1		1.5		8.7		4.3		0.7		0.2		1.4		1.0		6.6		4.4		6.1		0.9
Astrononion stelligerum																																				0.3														
Bigenerina irregularis																																	0.6													0.5				
Bolivina goesii														0.8				(1)				(1)																													
Bolivina hastata																		(1)																																	
Bolivina lanceolata	0.9	0.6	3.8	1.5	2.4	0.6	1.8	1.7	1.0	0.2		1.0		0.2	3.3	2.7	14.3	0.7		0.3	0.9	2.3		0.5	4.3	0.6		0.4		0.3							4.4	1.8		0.7	7.1	0.3		0.2								0.6
Bolivina lowmani	0.4	0.8		0.8	16.7	1.0	1.8	1.2	1.0	0.2		0.6	5.9	1.2		1.5		1.3		1.2		1.2		0.4		0.4		0.4		0.5		*			0.3		1.1		0.5		0.5		0.5						0.3		0.6
Bolivina paula	1.3	0.8		1.2		0.3	1.8	1.0				0.6		0.8		1.3		0.3				1.2	0.7	0.2		0.4		0.2		0.4		*			0.3		1.0		0.5		0.9										0.6
Bolivina striatula	0.9	0.8		0.7	7.1	1.3		0.7	2.0	0.4		0.4		0.8		0.4		0.7				1.7	*	0.5	2.2	0.2		0.2	2.1	0.4							0.7		0.2		0.2										
Bolivinita rhomboidalis		(1)		0.2				0.2				0.2		0.6		0.6		1.3				1.3		1.2		0.4		1.0		0.6		0.2						1.0		0.7		0.6		1.9						0.6		1.1
Borelis pulchra																										(2)				0.2			1.4		1.2											1.3		1.3			
Broeckina orbitulitoides										(1)																				*			0.6				0.2									0.3		0.3			
Bulimina marginata														0.6		0.2	14.3	(1)			*	0.9		*												1.1	0.3														
Bulimina cf. B. spicata																										(1)																									
Buliminella elegantissima		0.5	1.3	0.3			1.8	0.2	1.0	(1)				0.8		0.2		0.4	25.0	0.3	1.7	0.4		*		(1)		0.2										0.2												0.3	
Buliminella milletti						(1)										0.6		1.2				0.6	0.7			(2)		0.6	2.1	0.2		0.2						0.5				0.5										0.3	
Buliminoides williamsoniana																						(1)						0.2																						0.3	
Cassidulina subglobosa														0.2		0.6		0.3		0.3		0.5		1.2		0.2				0.5		0.2				0.3				0.4		0.2								0.3	
Cibicides deprimus																										(2)																									
Cibicides floridana										0.2				0.2		0.4		3.4		1.3	0.9	0.5		2.1		1.8				1.8		2.8	0.4	0.6		1.1		2.7		3.2		4.6		0.3		1.0		3.9		3.2
Cibicides refulgens																					0.2									*			(1)																		
Cibicides sp.																		1.3				1.0				(1)		0.6												0.3		0.7									
Clavulina difformis																																			0.1								0.2							
Clavulina tricarinata		(1)																															0.7												1.3		0.3		0.6	
Cribroelphidium kugleri				0.7				0.3				1.0		1.4		1.5		(1)			0.9	2.3		2.1						(1)		0.2						0.5				0.2		0.5								1.4
Cribroelphidium poeyanum	0.4	7.8	8.9	10.6	2.4	6.2	1.8	9.2	1.0	2.3	9.3	7.9		10.8	10.0	10.2		8.1		1.6	4.3	8.2		9.1		5.9		6.3	8.3	9.3	10.0	10.8		1.1		2.8	18.7	33.7	28.6	34.3	7.1	8.6		4.8				0.3		1.9		10.6
Cyclogyra involvens		(1)								(1)				*		*						(1)		0.5		(1)				*		0.2						0.2				(1)				0.6		*	
Cyclogyra planorbis	0.4	(1)		0.2				*		(1)				1.2		1.0	14.3	0.7				1.3		0.7	6.5	0.5		0.4		(1)		*										0.4		0.2								0.6
Cyclorbiculina compressa								*																																							0.8		1.3		0.3		
Cymbaloporetta squammosa																														(1)			(1)		0.3												0.8		*		
Discorbis mira		(1)		0.3				0.2								0.6		1.0		3.8		0.4		2.1		2.8		2.7		4.0		2.6		8.2		9.0		1.8		1.2		5.9		4.4		8.4		3.8		8.4		2.3
Discorbis rosea																				0.3						0.6				0.3				3.5		3.7				0.2				7.9		5.7		1.0		
Edentostomina? sp.																						(1)																														
Elphidium advenum		2.1		1.5		1.1	3.6	1.0	2.0	0.4		2.0		1.0		1.7		2.2		1.3	*	0.8		0.9		1.9		1.2		2.5		2.2		0.8		0.6		2.5		1.5		2.3		0.2		0.8		1.3		1.6		1.1
Elphidium gunteri galvestonense		2.9		5.0		10.8		9.9	1.0	13.6	2.3	8.3		8.5	3.3	10.9		5.6		19.9	0.9	0.4		4.4		9.4		8.6		14.3		17.8		3.9		4.7		2.1		11.3		0.8		1.2		2.9		0.3		3.9		4.6
Elphidium incertum mexicanum				1.0		0.5		0.2		1.0												0.2		0.4		1.5		0.7										1.2		0.2											
Elphidium sagrum																				0.6		0.3				0.3				(1)		0.4	(1)		0.3						(1)				0.8		0.6		0.3		
Fissurina cf. F. lucida	1.3	0.6	1.3	0.7		0.4	5.4	1.6		(1)	2.3	0.8	5.9	0.6	*	1.0		(1)			5.2	2.7	*	1.2		0.3	*	*	2.1	0.3		*					3.3	1.8		0.5	7.1	0.5		0.2								0.6
Fissurina pellucida														0.4								0.5				(1)							(1)								(1)												
Fissurina quadricostulata																						(1)		*																											
Fissurina radiata																																																				
Fissurina sp. "A"																		(1)				0.2		(1)																		0.2										*	
Fissurina sp. "B"																																						0.3													0.3	
Florilus grateloupi	0.4	0.4	5.1	1.7	*	0.3	7.1	1.0		0.2				0.2	6.7	1.5		0.6		0.3	0.9	1.5		0.7	10.9	0.6	8.3	0.4	2.1	0.4		0.2		0.3		0.3	2.2	0.3	28.6	1.0		0.5		0.2	*	*						
Fursenkoina compressa				0.3			1.8	0.5	1.0	0.2			5.9	0.6		0.6		0.3		0.3	13.9	3.7	9.1	0.7	2.2	(1)	*	*	2.1	(1)									2.2	0.7		0.2		0.2									12.5	0.6
Fursenkoina mexicana													5.9	0.2							0.9	0.7		0.5	2.2	(1)																										*
Fursenkoina pontoni					7.1	0.3		0.2	1.0	(1)		0.2				0.2					0.9	0.7		0.2				0.2																									
Guttulina australis																																						0.3					(1)									
Guttulina laevis															*							*		0.2		(1)							0.7					*		0.3		0.2									
Hanzawaia strattoni				1.0				0.7				0.6				1.9		2.6		1.6		1.3		1.6	4.3	2.2		3.9		1.4		1.3		0.3		0.3		0.5		2.0		2.9		2.7			4.2	0.6	5.9	2.6		4.6
Haplophragmoides canariensis		(1)																								(1)																									
Hauerina bradyi								0.2								0.4		1.2		0.6		0.3		0.9		2.0		1.4		0.9		1.3		0.6		1.2		0.3		0.2		1.2		1.9		0.5		1.3		2.3		1.1
Hauerina occidentalis																		(1)				0.3				(2)							(1)																		
Hauerina speciosa																		0.3																										0.3		0.5						
Heterostegina depressa																										0.2				0.2			*																	*	
Lagena laevis										(1)					3.3	0.4						0.2		*																											
Lagena striata																					0.9	(1)																														
Lamarckina atlantica																											*						*																	*	
Loxostomum porrectum																						*																													
Loxostomum sp.																										(2)																										
Massilina secans				0.2																																																
Miliammina fusca	17.9	4.8	3.8	2.1	11.9	0.4	7.1	2.3	1.0	0.2	2.3	1.0		1.2				0.3		0.3		0.7		1.9	4.3	0.7		1.6	4.2	0.5	10.0	1.5				0.9	1.1	0.2		1.0				1.9							17.6	1.9		2.6
Miliolinella circularis		(1)	1.3	0.5	2.4	0.4				0.5		0.4		2.5		1.0	14.3	4.1		2.6		2.3		3.3		2.2		2.7		2.1		3.5	0.6		2.5		1.5		1.0		3.8		2.9		0.8				1.6		1.4
Miliolinella fichteliana																						0.3		*		0.5		*		0.3		0.4	0.3		0.6								0.5		*		0.3		0.6		*
Miliolinella labiosa									(1)		0.2					*						(1)			2.2	0.4		0.2		0.2		*			0.7		0.6		0.5		*		0.4		0.2		0.3						0.6
Miliolinella suborbicularis		(1)							1.0	0.2												(1)		0.5		0.4				(1)												0.6										
Monalysidium politum		(1)																(1)				(1)				(2)				(1)												(1)										
Neoconorbina orbicularis	1.3	0.2		0.2					1.0	(1)				0.2				1.3		0.6		0.5		0.5		1.1		1.0		0.5								0.7		0.7				37.5	3.2	5.9	1.0		0.3	
Nodobacuriella cassis																										(1)							0.3																		
Nonion barleeanum																																	(1)												0.8						
Nonion depressulum matagordanum		0.4		0.3		1.2		0.5		0.2		0.8		0.6		1.0						1.7		1.6		0.2				0.4		*						0.7		0.4		0.7										2.3
Nonionella opima														0.2							7.8	1.3		*																												12.5	0.9
Nubecularia cf. N. lucifuga										0.2				0.2		0.2		0.6		0.6		0.6		0.2		0.6		0.2		0.3		0.4	(1)					0.3		0.5		0.3		0.2						0.3		0.9
Peneroplis bradyi																		(1)				*				0.5		0.2							0.6		0.2				0.3									0.6		1.1
Peneroplis carinatus				*		(1)		0.2		(1)								1.5		2.9		0.2		1.9		3.8		2.0		2.3		1.5		10.6	11.2			0.2		4.2		4.1		16.8		11.4		2.9		2.6
Peneroplis pertusus						(1)				(1)				0.2				0.7				0.3				0.4		0.6		0.4		0.2		1.3	1.9					0.5		0.2		0.5		0.3				*
Peneroplis proteus																				0.3				0.2						0.3				0.7	0.6									0.5		2.9		1.6		1.0		
Planorbulina acervalis																										(2)				(1)				0.6												*						
Planorbulina mediterranensis		(1)																												0.2												0.2										
Pseudobolivina walshi																					*	0.2																														
Pseudonodosaria torrida																						*																														
Pyrgo carinata																				0.3								*					0.6												0.3						
Pyrgo comata																																																				
Pyrgo subsphaerica	0.9	0.5				*	2.0	0.6	2.3	1.2		0.8	*	*		0.3		0.3			*	(1)		*	8.7	0.8		0.6	10.4	0.7	10.0	0.4		1.0			3.3	0.7			7.1	0.5		0.2		0.3		0.3	5.9	1.0		0.3
Quinqueloculina agglutinans		(2)				0.3				0.4								(1)		1.0		*		*	2.2	0.8		0.2		0.4		1.1		1.4		1.2		0.2		0.2		0.7		0.2		1.8		0.3		1.9		0.3
Quinqueloculina auberiana																						0.2				(2)								1.3	0.3									0.5		0.3				
Quinqueloculina bicostata				(1)																						(2)								0.3										0.1		0.8					
Quinqueloculina bidentata																																		0.7												0.3					
Quinqueloculina bosciana	2.6	2.4	8.9	2.6	14.3	0.9	5.4	2.1	14.3	2.4	2.3	2.2	5.9	3.3	3.3	4.6		6.1		1.9	2.6	7.8	18.2	9.6	21.7	4.6	16.7	5.1	25.0	3.6	30.0	2.8	2.0	2.2	7.7	4.4	*	2.7		5.6	22.2	4.8	50.0	0.3	4.2	2.2		1.3		5.5
Quinqueloculina collumnosa																										(2)		0.2		(1)		*	0.4	0.6								(1)		0.2		0.5				0.6		
Quinqueloculina funafutiensis																						(1)				(1)							(1)												0.3						*
Quinqueloculina lamarckiana		0.7				0.2		0.3		0.8		0.4		0.6		0.4		3.4		4.8		1.2		2.1		3.0		4.1		2.9		6.1		5.4		7.8		0.7		1.2		3.4		4.6		10.8		7.0		6.4		2.3
Quinqueloculina parkeri occidentalis																						*																								(1)						0.3	
Quinqueloculina poeyana	4.8	5.7	3.8	3.8	9.5	1.3	5.4	1.6	3.1	1.1	2.3	2.2		3.3	*	3.8		9.7		7.4		2.9		5.8	2.2	10.8		11.0		6.7		6.1		3.2		4.0	1.1	5.1	28.6	8.6	7.1	8.4		10.2		0.5		2.2	11.8	7.7		7.8
Quinqueloculina polygona														1.5		0.6		1.5		0.6		0.5		1.4		1.4		2.7		0.9		0.4		0.3		2.2		0.2		*		2.1		1.7		0.3		1.3		2.9		
Quinqueloculina seminulum	0.9	1.5		0.7	2.4	0.4	3.6	0.5		0.2				1.2				1.5				0.6		0.9		1.6				1.3		1.3		0.3				0.3		0.2	7.1	2.2		0.7		1.0				0.6		0.6
Quinqueloculina subpoeyana														*				0.4				0.5		0.5		0.2		0.2		0.2		0.2		(1)						0.2		0.2								0.3		0.6
Quinqueloculina tricarinata																																		(1)														0.3		0.3			
Rectobolivina advena																																																	0.2					
Reophax nana	0.4	0.3		0.2		0.4				(1)				0.6				0.3			1.7	1.3				2.2	(2)			(1)										0.3		0.2	7.1	0.4										
Reussella atlantica						(1)												0.4	0.3			0.2		0.2		0.4		0.2		0.2							0.3		0.2				(1)		0.2				0.3			
Rosalina candeiana	0.9	0.3		0.2	2.4	0.2				0.2		0.2						3.7	0.6			0.7		1.2	2.2	1.4		1.2	2.1	2.1	0.9	8.3	0.7		1.9		0.3				2.1		1.7		0.3		0.6		1.0		0.3
Rosalina floridana	0.4	0.5		0.8		0.3	7.1	1.0	4.1	0.4		0.6		1.4				1.5				1.3		1.2	2.2	1.0		1.2		0.5		0.4		1.0		0.3		0.5		0.7		2.4		1.5					5.9	1.0		1.4
Rotalia dubia																														*																					
Rotaliammina mayori																		(1)				0.5		0.2		(1)						*	91.7	2.7	50.0	0.6						(1)			*	0.3	25.0	2.9	5.9	1.0		0.3
Sagrina pulchella primitiva																0.4		0.7				0.5		0.7		(1)		1.4				0.2					1.1		*		0.8		1.5								1.1
Sigmavirgulina tortuosa										(1)								0.3				(1)		0.7		0.2		0.2		0.3					0.3		0.5		0.5		0.7		0.5						0.3		0.9
Siphogenerina costata																														*												(1)									
Siphonina pulchra																		0.4						0.2		0.3		0.2		(1)		*	1.6								0.5		0.2		0.5				0.3		
Sorites marginalis		0.3								0.2																(2)		*		0.4		0.4	1.3								0.5		0.7		0.3				*		0.6
Spirillina denticulata																						(1)																								(1)						
Spirillina vivipara															0.4	0.9						0.5		*				0.4		(1)														(1)		0.2				0.3		0.3
Spirolina acicularis														0.2										0.5		(1)		*		*																						
Spirolina arietinus																												*																								
Spiroloculina antillarum																		(1)				(1)				0.2				*		0.2		(1)										(1)		0.2							
Spiroloculina antillarum angulata										(1)								(1)				(1)				(2)		*		(1)				(1)						*						0.2						
Spiroloculina arenata																		0.3		0.3		0.2		*		0.4				0.4		0.9		0.3		0.9				0.2		1.7		1.9		0.8		0.3		1.3		*
Stetsonia minuta																						(1)																														0.3		
Textularia agglutinans															*		(1)		0.3			0.2				1.1		0.4		0.9				5.2		0.6				0.7		1.7		2.6		1.6		0.6		1.1
Textularia parvula			1.3	0.

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